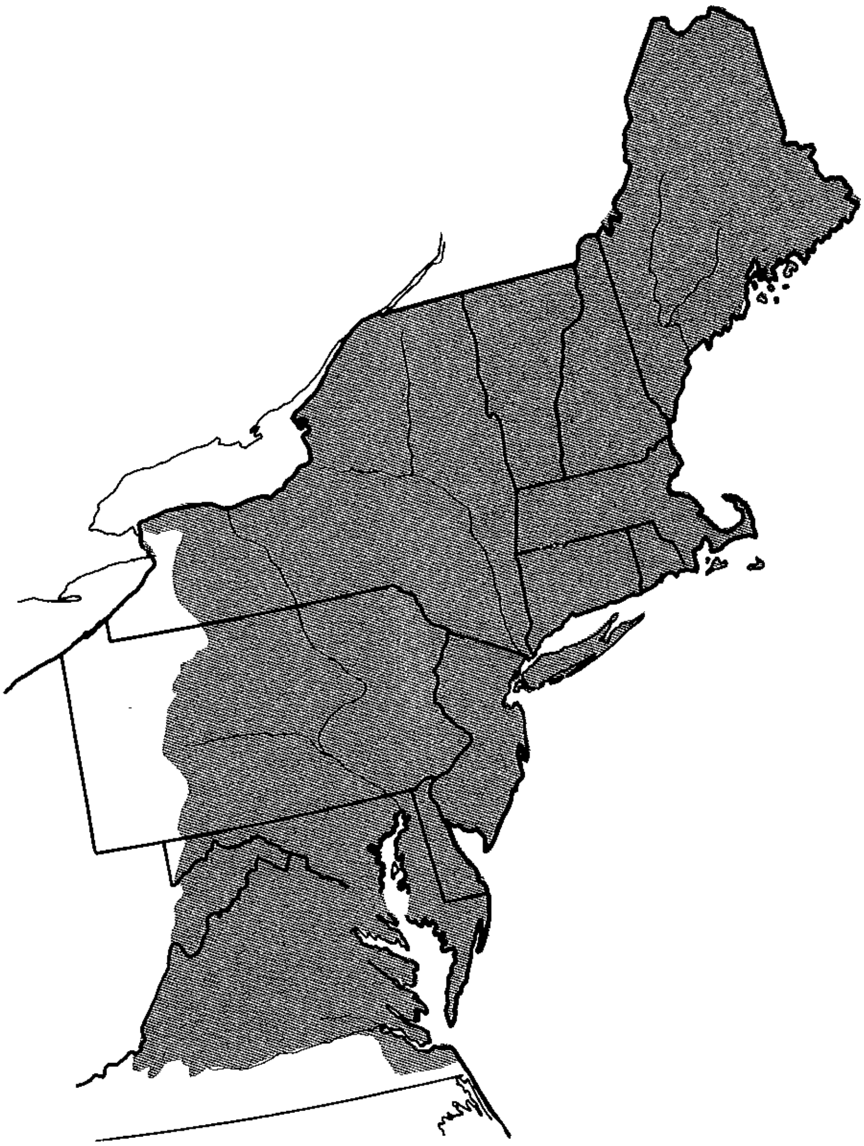
NORTHEASTERN UNITED STATES WATER SUPPLY STUDY

SUMMARY REPORT



July 1977

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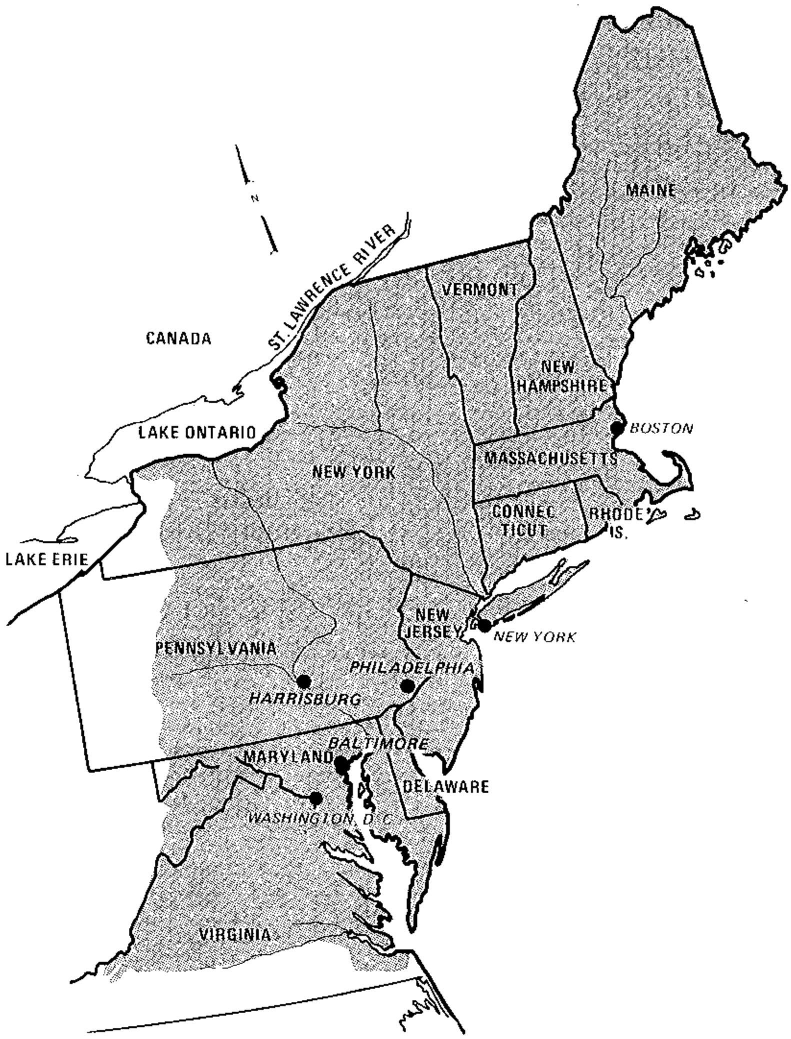

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NORTH ATLANTIC DIVISION
U.S. ARMY CORPS OF ENGINEERS

July 1977

NORTHEASTERN UNITED STATES WATER SUPPLY STUDY

SUMMARY REPORT
July 1977

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CHAPTER 1

THE NEWS STUDY

As a result of the severe drought in the Northeastern United States in the 1960's, the Congress enacted Public Law 89-298 directing the Corps of Engineers to work with appropriate Federal, state and local officials to plan steps to insure against future drought-related water shortages in the Northeast.

Studies of the 200,000 square mile region show that 50 million persons now live in the 13 states and District of Columbia. Studies also show that by the year 2020, population will increase to 80 million.

- **The Critical Areas**

The report findings clearly show that three metropolitan areas, New York, Eastern Massachusetts-Rhode Island, and Washington, D.C., have the most critical and immediate need to develop water supply sources to meet growing water demands.

CHAPTER 2

THE DEMAND FOR WATER

More than 14 million persons, living in the Northeast during the 1960's drought, were forced to restrict their water use to conserve dwindling supplies. Many areas came close to running out of water.

Since the drought, only one major water supply project has been built in the three most critical areas. Many water supply systems continue to register average consumption figures that are higher than their safe yields. In 1976 the New York City system had an average consumption that was approximately 170 mgd higher than its safe yield. The Newark, New Jersey water supply system supplied 36 mgd more than its safe yield and the system serving Boston delivered 17 mgd above its safe yield in 1976.

The number of people living in an area, their personal income, and the area's industrial growth, all affect total water demand. Projections of these parameters show that water use will continue to grow in those critical areas.

CHAPTER 3

WATER USE REDUCTION

If water supply cannot be increased to meet demand, then demand must be reduced to meet supply. Increasing price to reduce water used in these areas may be effective only if prices are increased by multiples of 100%. The equity of pricing policies would have to be carefully considered.

Temporary use control, during emergencies, can and does work for short periods of time if mandatory water use restrictions are applied. Some temporary reduction can also be obtained by reducing the operation of water using utilities such as power plants.

Long term reductions in water use can be achieved through conservation measures such as improved leakage control, use of water conserving fixtures and appliances, universal metering and public education programs. Such measures will be necessary if future water shortages are to be averted in major metropolitan areas.

Most methods to conserve water are within the jurisdiction of state and local government. Consequently, the ability of these agencies to implement use reduction techniques is a major consideration in estimating the effectiveness of conservation programs.

CHAPTER 4

SUPPLY INCREASE

Water availability can be increased through development of a variety of programs such as system improvements, surface water, ground water, wastewater and salt water.

- **System Improvements**

Connection of systems to provide joint use of high-flow skimming, ground water and reservoir storage provides many advantages that systems relying on single sources do not possess. Supplies can sometimes be effectively increased through interconnection.

- **Surface Water**

Surface water is the main source of supply in the three critical areas. This can be tapped by the use of on or off stream reservoirs that can supply water directly or can be used to augment stream flows where river intakes are the source. Occasionally suitable sites for small reservoirs can still be found near user areas. Large reservoir sites, however, are generally located away from population centers.

Estuaries could be a source of increased supplies in the New York and Washington, D.C. metropolitan areas. When these estuaries are polluted extensive treatment is required to make the water safe for long-term use.

- **Ground Water**

Ground water is another source of supply. Aquifers can be developed in stages, thereby offering flexibility in meeting changing demands. Ground water recharge areas would have to be monitored closely to prevent pollution.

- **Wastewater**

Wastewater, discharged to streams or aquifers used as water supply sources, makes up a large portion of present water used. This is found to be a questionable practice. Advanced wastewater treatment plants or carefully controlled land treatment can be employed to make indirect use of wastewater for a completely safe supply. Direct reuse of treated wastewater is not generally considered acceptable.

- **Salt Water**

Desalting is technically feasible, however, environmental problems and cost limit application of this technology.

CHAPTER 5

WATER SUPPLY AND OTHER PLANNING OBJECTIVES

In the three most critical areas, it was found that responsible officials and citizens plan to make their source and project decisions on the basis of factors that go beyond simply increasing supplies to meet demands. These additional considerations range from a project's impact on the environment, its flexibility to meet changing demands and demand patterns, impacts on population growth, cost, and reliability in terms of meeting the demand for water.

In order to facilitate decision making, potential projects for the three most critical areas are arrayed on decision trees. Each branch gives consideration to one or more additional planning objectives.

It is noted that each source decision, and each possible project, will give rise to questions and criticism from interested citizens and officials. But decisions must be made if sources are to be tapped and projects completed to meet the growing demand and reduce the risk of shortage.

CHAPTER 6

THE WASHINGTON METROPOLITAN AREA (WMA)

In addition to Bloomington Dam and Lake, the Corps of Engineers has already recommended the construction of two reservoirs and a pilot estuary water treatment plant to Congress. Even if these projects come on line additional work will be necessary to meet water supply demands in the area.

Area Profile

The WMA deserves special consideration because it is the Nation's Capital, a regional center, and because of the magnitude of its water supply problems. The 1970 population of about three million is a 39% increase over the 1960 population. Population is expected to be 6.8 million by 2020.

Water Demands

Water demands are expected to reach 515 mgd by 1980, 720 mgd by the year 2000, and 925 mgd by 2020.

Available Water

The major source of water in the WMA is the Potomac River. The river flow fluctuates widely around an average flow of 5975 mgd, a fact that must be considered in planning for peak demand periods. Other sources are the Patuxent River, Occoquan Creek and ground water.

Water Supply Programs

Water supply programs to meet the WMA demands have been formulated to reflect the considerations expressed by citizens and agencies, such as reliability, environmental quality, cost, growth control, flexibility and social and economic equity. Sources could be developed by upstream reservoirs, an estuary treatment plant, local water impoundments, raw water interconnections, ground water and treated wastewater. Demand reduction techniques are also considered. Formulated alternatives are displayed as decision tree branches and are designed to meet critical month and seven day maximum deficits. A local water saving policy would result in an aggregate total of 45 mgd by 2020 and is included in all branches. Bloomington Dam and Lake will be completed and its 135 mgd available by about 1980. It is included in all branches.

Decision Tree

Branch 1

Branch 1 is based on a mix of both proven and unproven technologies and minimizes large scale reservoir construction. It includes the Bloomington Dam and Lake, ground water, estuary treatment plants, interconnections of existing systems and local water impoundments.

Branch 2

Branch 2 relies exclusively on new or unproven technologies, undetermined ground water yields and emergency restrictions. The program minimizes land intensive reservoir construction and includes Bloomington Dam and Lake, ground water, advanced waste treatment and estuary use.

Branch 3

Branch 3, like Branch 2, is based on new and unproven technologies, undetermined ground water yields and emergency restrictions, but is less costly to implement. It includes the same projects as Branch 2, but places smaller reliance upon advanced waste treatment.

Branch 4

Branch 4 emphasizes surface water regulation by dam and lake projects. The branch represents maximum use of proven technologies and includes Bloomington Dam and Lake, a local impoundment, interconnections between existing systems, and the Verona and Sixes Bridge Projects.

Branch 5

Branch 5 is also based on the use of known and proven technologies and was formulated to utilize surface water regulation through dams and lakes. Bloomington Dam and Lake, Verona and Sixes Bridge Projects, and Local Impoundment Reservoirs were used in this branch.

CHAPTER 7

THE NEW YORK METROPOLITAN AREA (NYMA)

The Corps of Engineers has identified a specific project recommendation for an early action project for the NYMA: the Hudson River Project.

Area Profile

The area covers more than 9,000 square miles and includes 26 counties in three states and ranges geographically from metropolitan New York City to rural areas. Population projections show that the NYMA faces major population increases by the year 2020. Presently developed water sources will be totally inadequate to serve the needs of a growing population. The population in the area in 1970 was 18.9 million persons. By 2020, more than 26 million persons will live in the area.

Water Demands

Non-industrial per capita water use in various parts of the region in 1970 ranged from 70 to over 200 gallons per capita per day (gpcd) and averaged 135 gpcd. Industrial use ranged from almost zero to 50 gpcd. Total estimated demand for water by 2020 will reach 5.1 billion gallons per day.

Available Water

More than 100 potential projects were studied in developing water supply programs for the region. Major sources for the area are the Hudson, Delaware, Housatonic, Connecticut, Raritan and Passaic Rivers and ground water in Long Island and South New Jersey.

Water Supply Programs

Programs to meet the growing water demand in the NYMA have been formulated. These programs were represented at a public meeting on 19 March 1976. At that meeting the states of Connecticut and New Jersey indicated they could meet needs beyond the year 2000 from in-state sources. New York State requested that the feasibility of the Hudson River Project for early action be investigated.

Decision Tree

Branch 1

Branch 1 utilized the Connecticut State Plan, and small intra-state sources and South Jersey Ground Water for New Jersey. By the year 2020, New Jersey will probably need an inter-state source - in this branch the Delaware River was used. For New York, the Hudson River Project would be the early action alternative. By 2020, the Hudson River Basin Storage projects could provide the increased yield required. In addition, a conservation program to include metering, leakage control and domestic conservation measures would be implemented. This branch would require the least institutional rearrangement and could be the most easily implemented course of action.

Branch 2

Branch 2 presents an alternative for the State of New Jersey utilizing larger sources available. This branch would include the Delaware Diversion, development of South Jersey Ground Water resources, and by 2020, use of the Hudson River to meet its needs. For New York and Connecticut, this branch is identical with Branch 1.

Branch 3

Branch 3 presents an alternative for meeting the projected deficits for western Connecticut. This would involve development of the Housatonic River for water supply. For New York and New Jersey, this branch is identical to Branch 1.

Branch 4

Branch 4 presents the use of larger, more regional projects for each of the three states. It includes development of the Housatonic River for western Connecticut; development of the larger sources available to New Jersey including use of the Hudson River by about the year 2020; and implementation of a conservation program with development of the Hudson River for southeastern New York.

CHAPTER 8

THE EASTERN MASSACHUSETTS-RHODE ISLAND METROPOLITAN AREA (EMRI)

The most urgent demand for additional water supply in New England is in the Eastern Massachusetts-Rhode Island Metropolitan Area. Federal, state, and area officials agreed in 1970 that the Corps should study two projects for diversion of less than 200 mgd from the Connecticut River Basin, investigate the use of the Merrimack River for water supply, and determine the environmental impact of large diversions on the Merrimack and Connecticut River estuaries. Project reports have been completed and the Northfield Mountain and Millers River projects were recommended as Federal projects to meet near term needs.

Area Profile

The EMRI area consists of Rhode Island and all of Massachusetts except Berkshire County. The region contains 357 municipalities and a population in 1970 of 6.5 million. The population is expected to increase to 9.7 million by 2020. Of the current population, about 85% is urban.

Water Demands

Ninety-six percent of the area's population is served by public supply systems. The 1965 area demand was 749 mgd. It is expected to rise to 1287 mgd by 1990 and to 1893 mgd by 2020.

Available Water

The major supplier in the area is the Metropolitan District Commission, which served 37% of the 1970 population in Massachusetts. The potential water sources are the Merrimack, Ipswich, North, Taunton, Weweantic, Pawtuxet, Blackstone, Thames, Pawcatuck and Connecticut Rivers.

Water Supply Programs

Programs to meet the growing water demands have been formulated with consideration of additional objectives that appear to be significant in the area. Planning in the area has stressed the possibility of adding to existing systems.

Decision Tree

Branch 1

Branch 1 relies on Plymouth County Ground Water and on Connecticut River Diversions for water supply through the 2020 time frame. This branch shows one way in which the largest potential source of surface water, the Connecticut River, could be used.

Branch 2

Branch 2 is an alternative which could be implemented if (a) development of the Northfield Mountain and Millers River Projects was to be delayed to the 1990-2000 time period, and (b) no additional major Connecticut River Diversions were to be included for the region. Major projects include Plymouth County Ground Water, Merrimack River, Taunton River and estuary, and local developments.

Branch 3

Branch 3 includes early implementation of the Northfield Mountain and Millers River Projects which have been recommended for authorization by the Corps of Engineers. Projects under active study by local interests have also been included in the early time frame. Small projects would be used in the later time frame along with major development of either Plymouth County Ground Water or the Merrimack River. This plan makes greatest use of small projects and is considered the most likely to be implemented.

INTRODUCTION

Northeastern United States Water Supply - Summary Report

This, the final report to be prepared under authority of Title 1 of Public Law 89-298, is a summary of the most significant findings after comprehensive study of the water supply situation in the Northeastern United States. Since more than 150 published and unpublished reports, technical memoranda and data compilations, have been prepared since the initial Plan of Study was issued in 1966, the summary is necessarily most selective. In effect, the NEWS Report is actually contained in the many volumes referenced in the "Annotated List of NEWS Reports" which is attached at the end of this summary volume.

In November 1975, an *Interim Report - Critical Choices for Critical Years* was published and given wide distribution in the Northeast. Public meetings were held in each of the three areas found to have the most critical potential water shortages. These areas were the Washington Metropolitan Area, the New York Metropolitan Area, and the Eastern Massachusetts-Rhode Island Metropolitan Area. The *Interim Report* presented for each area a review of the studies which had been completed, described the demand-supply situation, outlined alternative programs which could be used to eliminate the risk associated with existing or potential water shortages and defined critical decisions which would have to be made if timely implementation of any of the programs or projects was to be accomplished.

The public meetings were intended to inform concerned people about the results of the study and to obtain their views on the alternative long range programs which had been developed for each of the respective areas. The meetings also determined whether local interests desired detailed feasibility studies of any project to meet near term critical needs.

One such project received the necessary support. New York State, New York City and adjacent counties requested that a survey scope feasibility report be prepared for a project which would use Hudson River water as a source of supply for the metropolitan area of southeastern New York. The feasibility report on the Hudson River Project is contained in the Appendix to this *Summary Report.*

This report is based on the *Interim Report* with the text and area programs updated to include current information and views.

Public Law 89-298
89th Congress, S. 2300
October 27, 1965

An Act

Authorizing the construction, repair, and preservation of certain public works on rivers and harbors for navigation, flood control, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

TITLE I—NORTHEASTERN UNITED STATES WATER SUPPLY

SEC. 101. (a) Congress hereby recognizes that assuring adequate supplies of water for the great metropolitan centers of the United States has become a problem of such magnitude that the welfare and prosperity of this country require the Federal Government to assist in the solution of water supply problems. Therefore, the Secretary of the Army, acting through the Chief of Engineers, is authorized to cooperate with Federal, State, and local agencies in preparing plans in accordance with the Water Resources Planning Act (Public Law 89-80) to meet the long-range water needs of the northeastern United States. This plan may provide for the construction, operation, and maintenance by the United States of (1) a system of major reservoirs to be located within those river basins of the Northeastern United States which drain into the Chesapeake Bay, those that drain into the Atlantic Ocean north of the Chesapeake Bay, those that drain into Lake Ontario, and those that drain into the Saint Lawrence River, (2) major conveyance facilities by which water may be exchanged between these river basins to the extent found desirable in the national interest, and (3) major purification facilities. Such plans shall provide for appropriate financial participation by the States, political subdivisions thereof, and other local interests.

(b) The Secretary of the Army, acting through the Chief of Engineers, shall construct, operate, and maintain those reservoirs, conveyance facilities, and purification facilities, which are recommended in the plan prepared in accordance with subsection (a) of this section, and which are specifically authorized by law enacted after the date of enactment of this Act.

(c) Each reservoir included in the plan authorized by this section shall be considered as a component of a comprehensive plan for the optimum development of the river basin in which it is situated, as well as a component of the plan established in accordance with this section.

NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY AREA

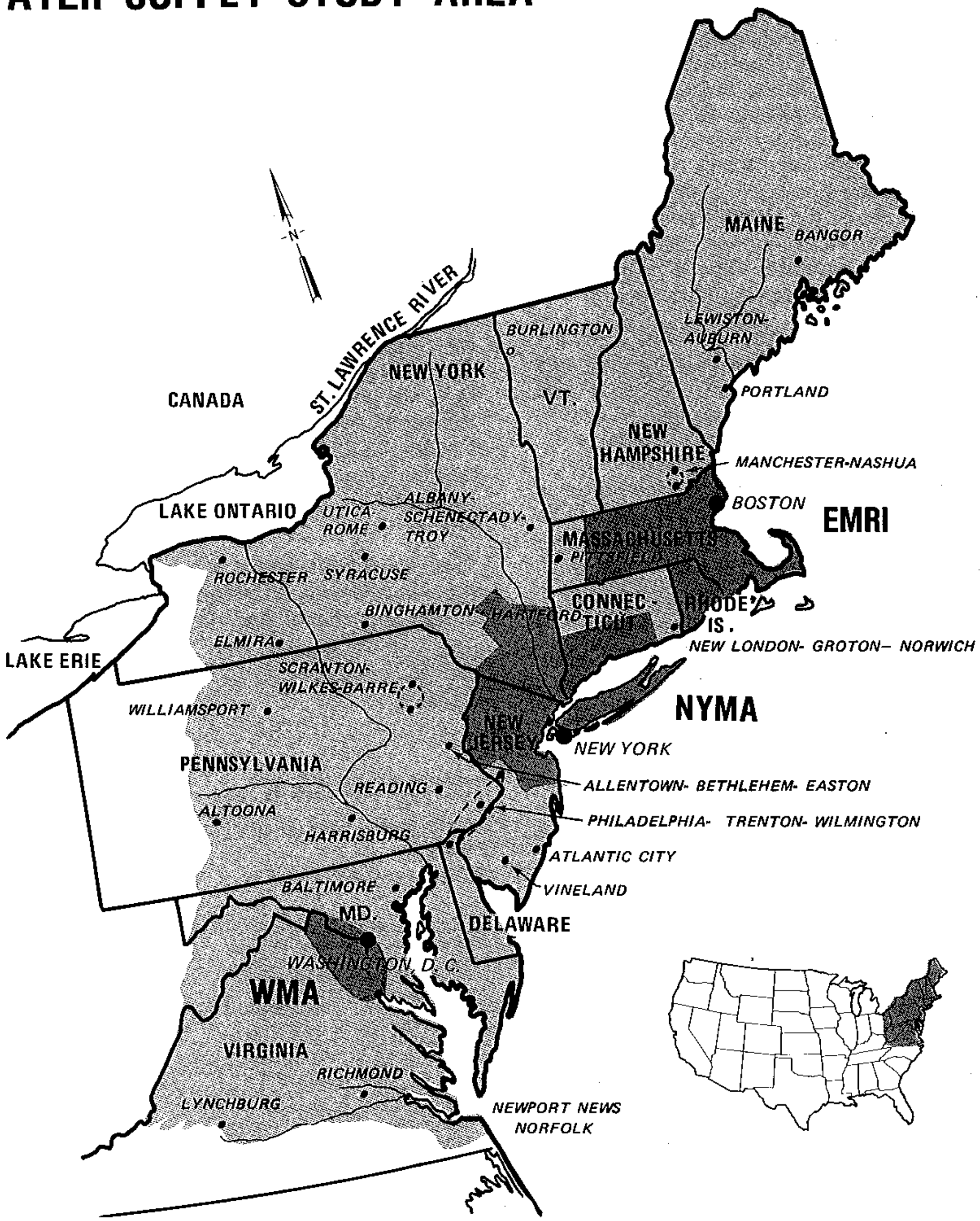


Figure 1

CHAPTER 1: THE NEWS STUDY

The United States is blessed with vast natural resources that have fostered and supported its growth, high standard of living, and development into a major world power. Water is among the foremost of the resources upon which our economy and our civilization depends.

Throughout the early phases of our history, there was little competition for water sources. Choices concerning projects to develop sources, the quantity to be supplied, alternative uses and the effects of different uses were much simpler. However, as population has grown additional water sources have been tapped and competition among users has greatly increased. This competition has precluded decisions to develop sources for water supply in time to avert shortages in the event of another major drought. As a result, water shortages are now emerging in urban areas, particularly in the Northeastern United States where about a quarter of our total population is crowded into only about eight percent of the nation's land. The drought of the early 1960's drew attention to this problem and caused Congress to take action.

That action, in 1965, was the enactment of Section 101, of Public Law 89-298 which states that the problem of assuring adequate supplies of water in metropolitan areas is one that affects the welfare and prosperity of the entire country. Congress recognized that the problem is of such magnitude and importance in the Northeastern United States that Federal effort is necessary to help solve it and therefore directed the Corps of Engineers to cooperate with appropriate Federal, State and local agencies in preparing comprehensive plans which could meet the long-range water demands of the people in the Northeast.

The Northeastern United States Water Supply (NEWS) Study region extends about 1,000 miles from Northern Maine to Southern Virginia, averaging 200 miles in width from the Atlantic Coast. The study area involves nearly 200,000 square miles of land, populated in 1970 by about 50 million persons in the states of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New Jersey, Delaware, the District of Columbia and portions of New York, Pennsylvania, Maryland, West Virginia and Virginia.

By the year 2020, the population in this region probably will have grown to 80 million. This increased population will still be concentrated in the five major metropolitan areas of Boston, New York, Philadelphia, Baltimore and Washington. About 60% of the present population already lives in these areas. Since urbanization is a continuing process, the portion of the region's population living in and around these urban centers will in all probability continue to increase.

Purpose

The purpose of this report is to describe the work done in the NEWS Study. The planning process and study analysis led to identification of the three most critical areas and most of the following discussion concentrates on these areas. The report displays the major alternative sources of water supply available, together with their advantages and disadvantages, so that the public and governmental agencies may hold responsible discussions and make knowledgeable decisions regarding future water supply. Additionally, the report provides in the Appendix, a feasibility report on the Hudson River Project, proposed to meet immediate near term needs for Southeastern New York. A summary of information developed during the entire NEWS Study is included in the attached "Annotated List of NEWS Reports".

The Critical Areas

The authorizing legislation for the NEWS Study directs attention to the water supply problems of metropolitan areas. The classification of Standard Metropolitan Statistical Areas (SMSA) used by the Bureau of the Census was adopted as the mechanism for identifying those areas that would be studied under NEWS. On the basis of preliminary population projections, thirty-one urban areas were identified as containing all current and emerging SMSA's in the Northeast. The water sources and water supply facilities serving these areas were examined to estimate the amounts of water that could be delivered to each area's population and industry during a drought. Population projections were then made and translated into future water supply demands for publicly supplied municipal and industrial water. The projections extended to the year 2020.

Comparison of each area's water supply demand with water supply capability led to an identification of those areas with an immediate near term need (prior to 1990) for increased supply capability, and those with longer range needs. Immediate needs were noted initially for the following five areas:

- Eastern Massachusetts-Rhode Island
- New York Metropolitan Area
- South Central Pennsylvania
- Baltimore
- Washington, D.C.

As studies progressed, it became apparent that the problem in the South Central Pennsylvania and Baltimore areas were not as urgent as originally thought. Therefore, since this report deals only with the urban areas projected to experience near term problems, the South Central Pennsylvania and Baltimore areas have not been included.

Information on the detailed studies made of the South Central Pennsylvania Area is contained in separate reports referenced in the Annotated List. Detailed studies were not made of the Baltimore area because adequate information had been developed in local studies.

A number of separate studies and reports have been completed for each of the three most critical areas. These studies form the basis for this report and are completely listed in the Annotated List. They range from examination of social, economic and environmental costs and benefits to new technologies, demand reduction and hydrologic analysis.

The twenty-six other urban areas with potential long range problems have been studied to determine demands and supply capabilities. The information is available as a separate report, as referenced in the Annotated List.

The Planning Process

Planning for such a large and complex region requires careful and orderly analysis. To accomplish this a series of planning steps has been applied to each area studied. The initial two steps were required for all areas and the remaining four steps for the three most critical areas.

1. Examination of the Problem. Projected water demands were compared with available supplies for the 31 urban areas in the region to determine where potential shortages exist. Those areas having a potential for critical shortages prior to 1990 were identified.

2. Development of Solutions. Technically feasible alternative solutions were developed for all areas and alternative solutions consistent with the individual areas' broad planning objectives were developed for the three most critical areas and for South Central Pennsylvania.

3. Identification of Critical Implementation Factors. An examination of the key effects of implementing each project was made to select the projects having the most positive impacts while achieving additional planning objectives. Where the key effects were sensitive to modification of certain project features, the modifications were made and the projects grouped into alternative regional programs.

4. Determination of Annual Charges. In the *Interim Report* of 1975, "cash flow" (i.e., annual charges) for each program was determined for two rates of interest to compare funding at the Federal water supply interest rate with funding at the estimated local government borrowing rate. In this *Summary Report*, annual charges are shown at the Federal rate for projects authorized or proposed to be authorized as Federal projects, and at estimated local rates for all other projects.

5. Timing of Decisions. In this report, time horizons have been adjusted for each critical area to show the earliest decade in which major projects could come on line. In the Washington Metropolitan Area, Bloomington project will be able to provide water by 1980, or shortly after, and that year is shown as a focal point for planning in the WMA. In the New York Metropolitan Area, the only major project for which decision making has begun, the NEWS Hudson River Project, could not be operational until late in the 1990 - 2000 period so that the year 2000 became the first planning target for the NYMA. Major Federal projects have been proposed in NEWS reports for the Eastern Massachusetts - Rhode Island Area and therefore 1990 became appropriate as the early action planning goal in EMRI.

6. Determination of Acceptability. NEWS studies have been discussed and reviewed in numerous information meetings with various groups in the NEWS area throughout the duration of the study in order to determine the acceptability of the technically feasible water supply programs developed in the course of the work. Final formal public meetings on the long range programs were held in March 1976 in each of the three critical areas. The *Interim Report* was the basis for the hearings and it included a "decision tree" for each area consisting of "branches", or alternative arrays of programs to meet water supply needs. The programs shown in this *Summary Report* have been revised in accordance with the comments and views of local officials and interested parties expressed at formal public meetings, at informal information meetings, and by written communications.

In addition to meeting the primary objective of meeting water supply needs other planning objectives have been considered.

Reliability: The ability to assure adequate quantity and quality of water supplies during conditions of severe drought.

Flexibility: The capability of being altered to efficiently accommodate future changes in projected water demands, and economic, environmental, social and technological factors.

Timeliness: The capability of being implemented in time to meet water supply and other needs as they occur.

Equity: The ability to provide for the equitable distribution of the benefits and costs of natural resources development.

Planning Premises

As study and planning for the three most critical areas progressed, a number of basic general premises were developed based on data and evidence collected by the Corps of Engineers and other Federal, state and local agencies. Those relevant to this report are:

- The net effects of continued population and economic growth will be to create correspondingly greater demands for water supply, only slightly offset by increased use of water saving fixtures and appliances.
- Water supplies will be significantly increased by deliberate indirect wastewater reuse, for instance, by returning treated wastewater to surface and ground water sources of supply but direct reuse of wastewater will not be generally acceptable during the time frame of this study.
- There will be no changes in the ownership of existing water supply utilities. However, in certain areas the merging of small public systems into larger regional systems may increase efficiency.
- Droughts will continue to occur periodically and public demands for water will be met.
- Demands cannot be materially reduced through legislation or changes in water use habits prior to the mid-1990's, except where important elements in good water system management are lacking such as metering and effective leakage monitoring and control. Prices would have to be increased to several times current levels to appreciably reduce demand if pricing alone is made the basis of a conservation program. New data on the effectiveness of water charges will become available from several parts of the country in 1978 and later.

CHAPTER 2: THE DEMAND FOR WATER

Water is such a readily available resource that it is generally taken for granted. To the average person, water is like air — something that is simply there to be used routinely for any purpose and in any quantity necessary. Its abundance is so taken for granted that it appears in a cliche: Free spenders are said to "spend money like it's water."

Not until water becomes scarce, or temporarily unavailable, does the individual realize how dependent he is on water in his everyday life.

Health, sanitation, and personal cleanliness all depend on water. Business and industries employing millions of workers, and providing goods and services for additional millions, could not function without plentiful water for manufacturing processes and cooling. The urban and suburban environment, with its treasured green spaces, parks, lawns, and gardens, would suffer if man did not supplement nature's rainfall. Municipal health and safety services such as street cleaning and fire fighting could not exist without adequate water.

When water becomes scarce during droughts, almost everyone suffers economic losses, as well as reductions in standards of living. This is especially true in large metropolitan areas where the problem is magnified by large populations and complex organizational authorities involved in water supply.

Unfortunately, droughts, like heat waves, are natural weather events that reoccur at random intervals through the years. A study of New York rainfall records shows a history of droughts as well as excesses (see Figure 2-1). These records are an example of periodic rainfall deficiencies throughout the Northeast. Although much of the Northeast has enjoyed a period of excess rainfall in recent years, it is certain that rainfall deficiencies will occur in the three most critical areas at intervals in the future.

The drought in the Northeast during the early 1960's presented a classic example of the ramifications of a water shortage. Water supplies dwindled and drastic emergency measures had to be taken to husband remaining supplies. More than 14 million of the 50 million persons living in the Northeast were restricted in their water use

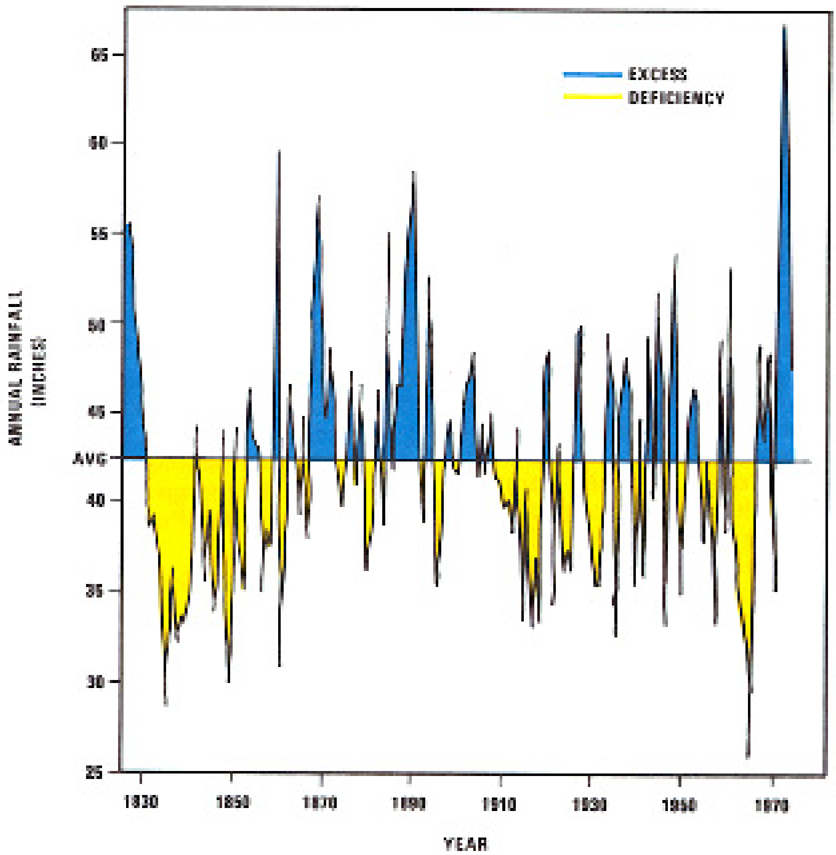


FIGURE 2-1. ANNUAL AVERAGE RAINFALL IN NEW YORK CITY 1826-1974

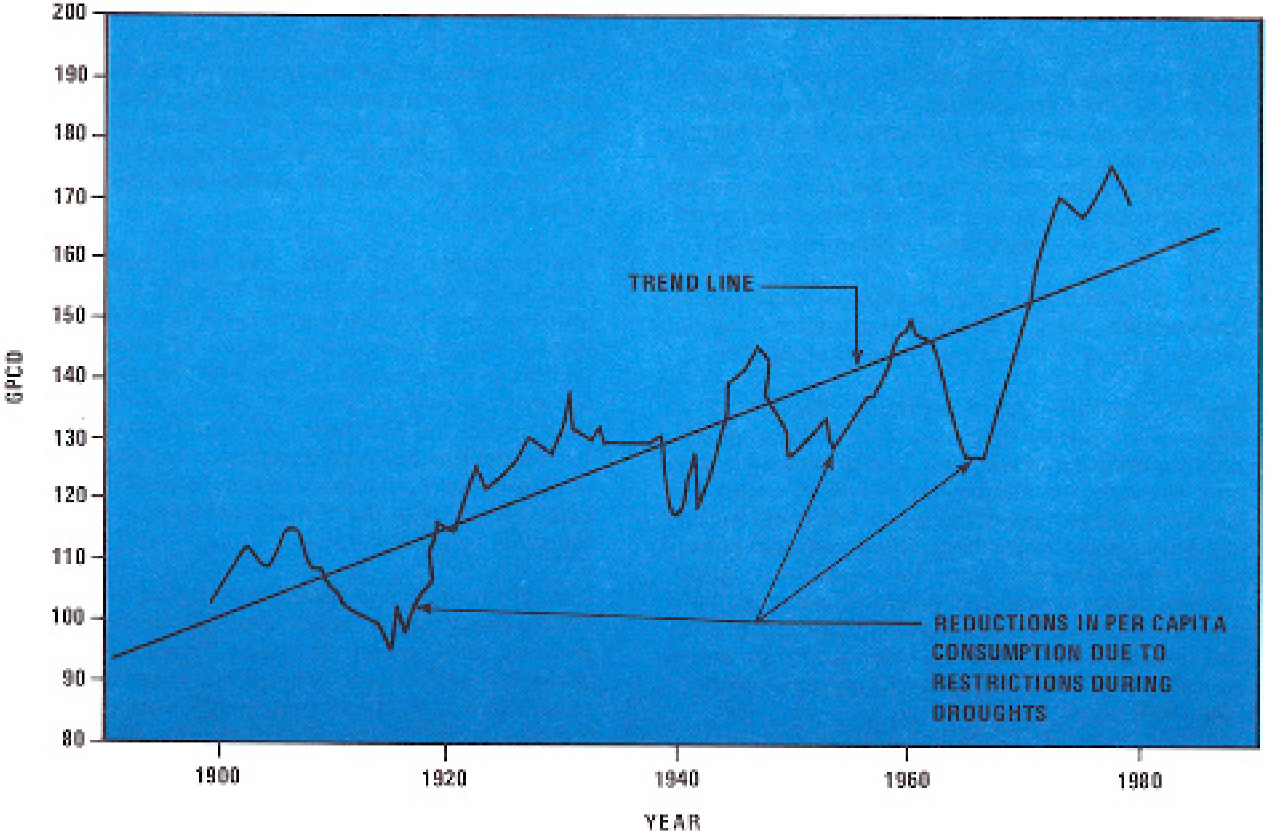


FIGURE 2-2. HISTORIC PER CAPITA WATER CONSUMPTION — NEW YORK CITY

and suffered personal discomfort, inconvenience and economic disturbance. Figure 2-2 shows a reduction in per capita water consumption in New York of approximately 15% during the 1960's drought and similar reduction during other droughts. This pattern of reduction is fairly typical of the per capita consumption curves displayed by other areas. It can also be noted that per capita consumption quickly returns to or exceeds the long-term trend line showing a slight rate (¾ gpcd/yr) of increase over time. Even with rigidly enforced restrictions, many urban centers came dangerously close to running completely out of water during the 1960's drought.

Since the drought ended in the middle 1960's, only one major water supply project has been built in the Northeast and that was a modification of the existing Round Valley Reservoir by New Jersey to increase yield by 80 mgd. No other major water supply projects have been built to serve the three most critical areas. Many water systems in the three most critical areas today find themselves routinely supplying more water than they could in a drought. For instance, the New York City system has a safe yield, based on the 1960's drought, of about 1300 mgd. Yet in 1976 the average consumption was 1,470 mgd and it has been higher in previous years.

In Northern New Jersey, the Hackensack Water Company has a safe yield of 82 mgd. Its 1976 average consumption was 98 mgd. The Newark Water Supply System in 1976 saw consumption reach 86 mgd, a full 36 mgd above its safe yield of 50 mgd.

In the Washington, D.C. Metropolitan Area, in 1976, the peak one-day water consumption from the Potomac River was 400 mgd. In 1974, the peak one-day demand had reached 448 mgd. By contrast, a minimum recorded one-day Potomac River discharge of 342 mgd occurred in 1966 as measured at Point of Rocks, Md.

The Metropolitan District Commission in Boston in 1976 delivered an average 317 mgd with a system that has a safe yield of only 300 mgd.

Water use in a region is largely determined by population, personal income and the types and extent of industrial activity. The relationship between these parameters and the amount of water used in the critical areas was studied in order to estimate future per capita water use. Projections by the Office of Business Economics of the U.S. Department of Commerce of population, personal income and earnings by manufacturing industries for the entire Northeast were used in the study and are shown on Figure 2-3.

If growth could be abated by not supplying additional water, no new solutions for water supply would be necessary. Unfortunately, growth generally occurs with little attention given to the quantity of water available under drought conditions. Developers and the general public appear to be optimists regarding water supply and growth continues as if normal or non-drought year supplies would always be available. Many utilities, consequently, maintain service during normal or wet years that could not be sustained under drought conditions.

NEWS studies based on moderate growth and use projections indicate that the gap between available water supplies and use, even in non-drought years, is narrowing perceptibly. Therefore the next major drought to occur in any of the three most critical areas will have more severe impacts than the 1960's drought. The cushion between safe yield and use was thin then; it is gone now. Not only is the population growing, but it is using more water per capita now than in the 1960's because of the growing domestic and industrial investment in water-using, work-saving devices.

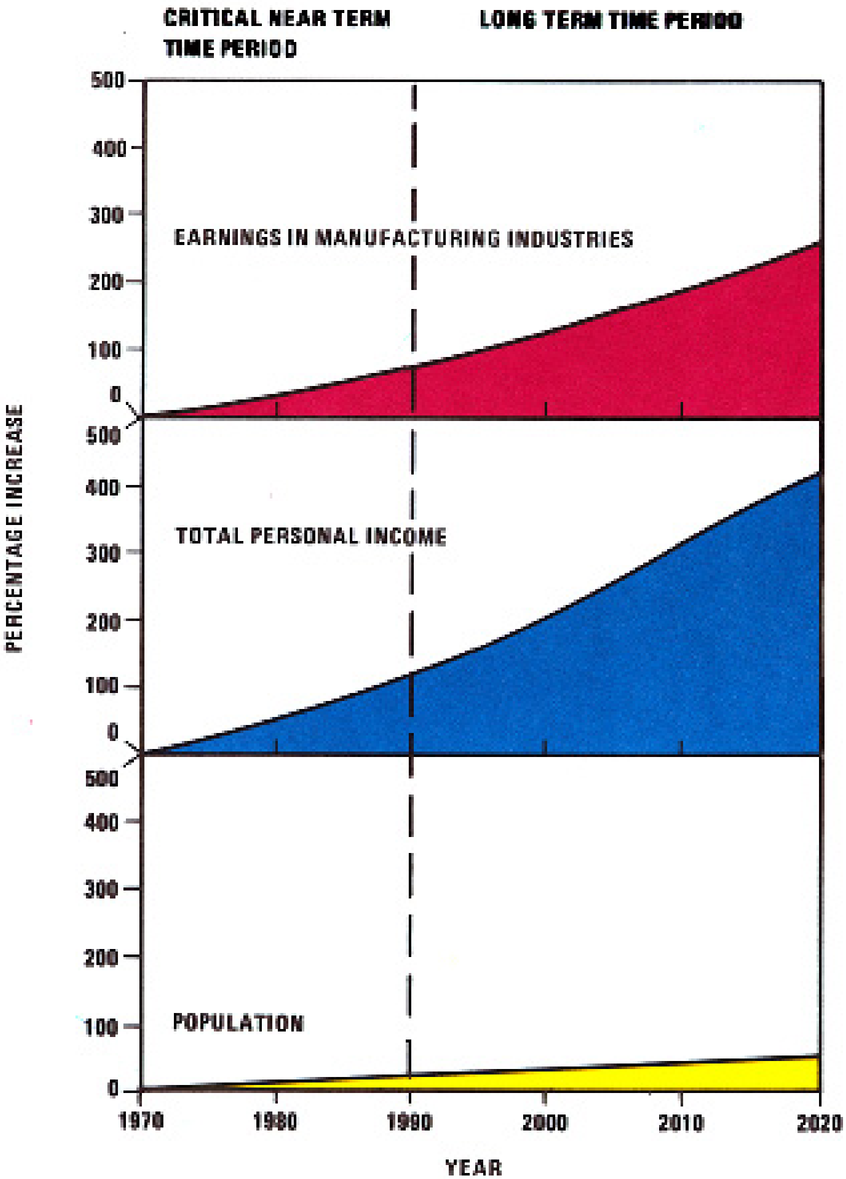


FIGURE 2-3 PERCENTAGE INCREASES OF PERSONAL INCOME, EARNINGS IN MANUFACTURING INDUSTRIES, AND POPULATION IN THE NORTHEAST – 1969-2020

CHAPTER 3: WATER USE REDUCTION

When supply and demand are out of balance, one or the other or both, can usually be adjusted to restore the balance. Such would appear to be the case with water supply and demand. When the population demands more water than is available, then either the supply must be increased to meet the demand or water use must be equitably reduced to the level of available supply. Neither step is easy to implement, but both were investigated.

Reduction in Use

Restoring the supply-demand balance by controlling use would appear to be a satisfactory long term solution to a water shortage problem. There is, however, no proven technique for implementing this step. Long term use control has never been attempted in this country and the equity of applying restrictions to one region and not another would have to be carefully considered.

However, there are a variety of tools available to reduce water use.

1. Water Conserving Plumbing Fixtures,
2. Pricing,
3. Industrial Controls,
4. Leakage Control,
5. Zoning Controls on Growth, and
6. Public Education Campaigns.

As we become more aware of our natural resource shortages and become more conscious of the needs to conserve them, these tools will be more intensively used. The problem of resource conservation is most critical in major metropolitan centers. New sources of water are, with currently available technology, normally well beyond the jurisdictional boundaries of the urban centers. Development of these sources requires authority beyond what the local area usually possesses and is costly. Conservation techniques are a viable method of reducing the urgency for these developments.

The responsiveness of users to these conservation practices will depend largely on the nature of the area in which they are applied. For example, pricing may be very effective in reducing use in an area where the housing is primarily suburban in nature and in which there is limited rainfall and high temperatures. These factors would generally indicate greater outdoor uses of water and these uses are sensitive to pricing policies.

In an area with greater density and more multiple unit dwellings, pricing would be much less effective in reducing water use. As a result, the decision as to which of these policies should be applied should be made on an area by area basis.

If the metropolitan centers are to avert water shortages, it is likely that they will have to implement conservation measures. For example, New York City, Nassau and Westchester Counties would have to reach beyond their boundaries for any new water sources. The nearest potential source areas, the mid-Hudson counties, have agreed that the metropolitan center must be metered and must attempt to conserve water before new source development is allowed to proceed.

NEWS projections of water use reflect as much as a 250 percent increase in industrial recirculation in critical areas. Additional reductions in future water withdrawals for industrial use can be obtained if state and local authorities require greater industrial recycling. This is, however, difficult to implement since industries may leave an area if forced to use costlier processes. Domestic use can be reduced by intensive education programs but the public may not be willing to change habits in any but drought years.

Permanent reductions in demand are attainable through improvements in water using equipment and processes. Such water economies can be encouraged in new facilities or incorporated during rebuilding or refurbishing of existing domestic, commercial and industrial facilities.

Since the cost of installing water saving fixtures is high in existing structures, it is likely to occur only in new or renovated structures, and not in existing facilities.

Institutions exist on the local level to carry out permanent demand reduction through the adoption of new plumbing codes and changes in water metering and rate setting. Thus these changes can be implemented without new institutional arrangements.

Institutions also exist at the local level for the control of growth through zoning or taxation. It is unlikely that these authorities could be applied effectively throughout any of the three most critical areas because of overlapping jurisdictions. If applied in one locality, growth would be shifted to another nearby locality resulting in similar overall demands for the entire area.

Changes in the price of water could be effective in reducing overall demand. However, as indicated above, the nature of the area would determine the effectiveness of the price change. In some areas price would have to be raised in multiples of 100 percent to have a significant effect. At such price levels, questions of equity have to be considered. Large price increases have broad implications concerning windfall profits, tax structures, the possibility of discriminating against less affluent segments of the population or against certain geographic areas. The ability to implement a demand reduction pricing policy covering both public and private utilities as well as diverse political jurisdictions remains an unsolved problem. Whether the technique can be fairly and justly applied to water supply is a question that will have to be answered in investigations beyond the scope of this study. Until resolved, pricing as a means of reducing or limiting use on a permanent basis must be evaluated separately for each area.

Public education campaigns have the potential for being an effective tool for reducing use. Institutions exist at the local level to carry out this type of effort. However, the effectiveness of this device in reducing use is virtually impossible to quantify at the present time. The success of anti-litter campaigns in certain metropolitan centers indicates that the technique can have value by raising the consciousness of the public to the objective.

Temporary Use Control

In emergency or crisis situations a temporary reduction of 10% to 25% in peak daily use can be accomplished through either voluntary or mandatory restrictions. This technique of reducing water use can be readily employed, but only succeeds when a real emergency exists and people are willing to make sacrifices to meet the emergency.

Voluntary restrictions normally result in smaller reductions than mandatory restrictions. However, neither method is considered likely to produce enduring major reductions in water use.

Time restrictions would include prohibitions on certain water uses during certain hours, thus reducing peak use to more manageable levels.

Use related restrictions involve outright prohibitions of such water uses as lawn or garden watering, washing of cars or streets, operation of ornamental fountains not fitted with recirculating devices, filling of swimming pools and use of air conditioners with once through water cooling.

Some temporary reduction in water use might also be obtained by reducing the operation of water using utilities. For instance, if restrictions were placed on the use of electricity, portions of power plants needing large amounts of cooling water could be shut down.

Whatever the method or methods selected, they must be reliable if they are to successfully reduce water use. Water restriction drills during periods of normal water availability could be considered a necessity. In addition, restrictions should affect all consumers equitably, and institutional arrangements must provide for rapid and certain enforcement of use restrictions.

Summary

If the four key tests mentioned in Chapter 1 are applied to the concept of reducing water use, this proposal is not without problems. Use reduction is not known to be reliable for long periods, since it has not been tried. Neither permanent nor temporary reductions can be instituted in a timely manner without the full and immediate public cooperation that comes from practice. Neither offers flexibility - the use of water cannot be turned on and off at will without creating severe economic, political and social shock. Moreover, it is difficult to be completely equitable to all water users when applying restrictions.

CHAPTER 4: SUPPLY INCREASE

If the use of water cannot be curtailed sufficiently to balance the supply-demand equation, then the only possible alternative is to increase the supplies available. The Northeastern United States is blessed with abundant undeveloped water resources capable of being developed to provide adequate water to meet demand. However, the competition between users has delayed critical development. The available sources are: System Improvements, Surface Water, Ground Water, Wastewater and Salt Water.

In considering which sources of water should be employed and which methods used to develop those sources, it should be kept in mind that water use is cyclical. Figure 4-1 shows the variations in water use for New York City over the course of a year. Water use varies even more sharply from hour to hour, and day to day.

Cyclical use is an important element when establishing the design basis for projects and programs to meet water demands in the future. Reservoirs, for example, have large storage volumes and can meet short term peak demands even though their design is primarily to meet average demands over a long period of time. Conversely, water systems that draw directly from a river must be designed so they can meet short term, peak demands, since there is no storage or reserve upon which to draw.

System Improvements

One of the fastest ways to increase available supplies, using existing systems is by interconnecting those systems to assist in balancing short term peak demands. Pipelines and pumping stations at key points can then shift water between systems and thus better use in-system storage. Significant increases in yield can be made when interconnected systems include one with a reservoir and another with a large stream available for high flow skimming. When two or more systems having these features are connected, each can depend substantially on the high flow skimming equipment when river flow is sufficient, then each can switch to the reservoir when natural stream flow is low.

The pumping stations and pipeline or tunnel systems needed to shift water in an interconnected system are likely to be large and expensive. However, because interconnection can be accomplished using existing systems and through existing institutions, this method of increasing supply can be implemented more quickly than new sources can be developed.

If interconnection is not feasible, new sources of water supply must be developed. The major new sources of water for each of the three most critical areas are surface and ground water, treated wastewater and salt water.

These sources can be developed by using reservoirs, river intakes, wells, wastewater renovation plants or desalting plants.

Surface Water

Surface water can be developed as needed with river intakes, or it can be impounded in reservoirs for later use. Reservoirs vary widely in size, use and location. They can be used to store water for direct use via pipeline or tunnel or to augment stream flows for increased down stream use. High flow skimming water from a stream pumped into an off stream reservoir, is also frequently employed.

The location and size of reservoirs are generally dictated by a combination of topography and urban development. Suitable sites for small re-

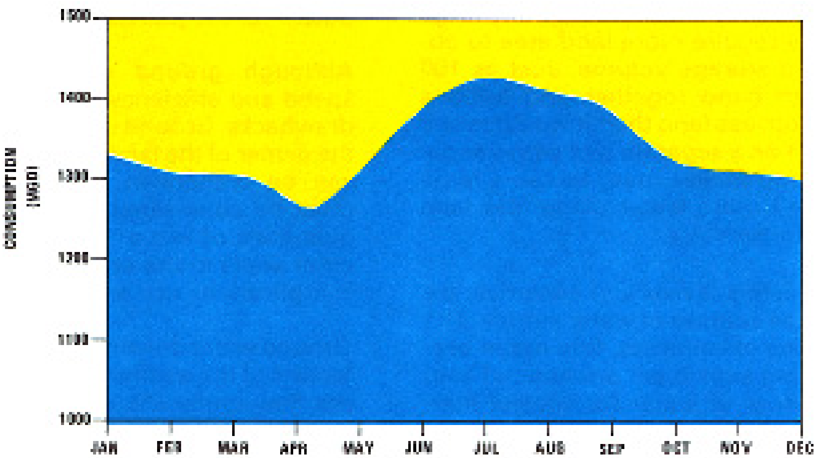


FIGURE 4-1. AVERAGED VARIATIONS IN WATER CONSUMPTION IN NEW YORK CITY — 1971

servoirs can occasionally still be found in or near the metropolitan centers they would serve. Large reservoirs, however, must be located away from highly populated metropolitan areas because few lightly populated and topographically suitable sites remain in those areas.

Large reservoirs create complications that have nothing to do with the design or yield of a reservoir, but rather involve controversies between political jurisdictions and institutions. Usually these jurisdictional questions can be solved only by the intervention of the state or Federal Government which must decide whether water users in one river basin can go beyond their political boundaries and into another area or watershed to get water. Settling jurisdictional disputes, of course, often takes years.

When a large reservoir project involves the transfer of water from one major river basin to another, the effects on both donor and receiver areas must be carefully evaluated. Obviously, taking water from a river basin will have an effect on the basin. The additional water in the receiving basin will also have an effect on that basin's rivers. Consideration must be given to both beneficial and adverse consequences associated with major alterations to stream flows in both basins.

In summary then, small reservoirs, if they can be located close to the users, can often be built fairly quickly without major jurisdictional complication. Their individual safe yield, (amount of withdrawal that can be sustained during the design drought) however, is necessarily small. Large reservoirs, because of their size and because they usually must be built away from the user area, take a correspondingly longer time to build. They do, however, provide a supply which will be adequate for a longer period of time.

One source of controversy regarding reservoirs is their land requirements. Generally, several small reservoirs are not as efficient in terms of land requirements for a given safe yield as one large one. They usually require more land area to obtain an equivalent storage volume. Just as 100 store owners can band together and build a shopping center on less land than it would take if each of them built on a separate plot with a separate parking lot and access road, so can a large reservoir impound more water using less land than many small reservoirs.

The tidal lower reaches of rivers, or estuaries, are often overlooked as sources of water supply. The freshwater portions of estuaries, (the upper sections not containing significant amounts of salt) are potential sources of water for coastal metropolitan areas such as Washington and New York. These are, unfortunately, often grossly polluted by untreated or poorly treated wastewater discharges and storm water runoff.

With the accelerated abatement of water pollution mandated by the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500), estuaries may become more useful sources of additional supply in the future.

Estuaries can be used before the zero pollution mandate by Congress becomes effective, by withdrawing the water and treating it in conventional water treatment plants before putting it into a distribution system. Because conventional treatment plants are not designed to treat water that is as highly polluted as may be found in many estuaries, this method involves certain public health risks. It may be acceptable to live with those risks for limited periods of time in an emergency, but not for longer periods. This method, however, may be implemented in a fairly short period of time by existing institutions. Advanced waste treatment methods can render virtually any water potable.

The Congress has authorized a large pilot or prototype treatment plant on the Potomac estuary to determine the safety and feasibility of a variety of techniques to use estuary water as a potable water supply source. Construction began in 1977.

Ground Water

Another major source of additional water supply is ground water. Large ground water sources exist near metropolitan areas lying in the coastal plains of the Northeast. Well fields to tap such aquifers are technically feasible and can be built as needed. A typical system will normally include pumps at the well heads, chlorination equipment, pipelines to distribute water and perhaps small reservoirs and pumping stations along the distribution line.

Large amounts of energy must be provided to run the pumps, and back up power systems, such as diesel-fuel generators, must be built to provide power for the pumps in case of electrical failure.

Although ground water development offers speed and efficiency of construction, it also has drawbacks. Ground water may be the property of the owner of the land over it. Before groundwater can be withdrawn, individual property rights must be considered, since withdrawal of large quantities of water from an aquifer may cause other wells in the aquifer to go dry. Major legal complications can arise in such cases.

Ground water development also requires the protection of the aquifer recharge areas. Since aquifers flow under the surface for many miles it is possible that contaminants entering the ground water miles away could flow through the aquifer to the well field, thus contaminating the water.

Wastewater

Another source of additional water that can be used to meet increasing demands in the three most urgent areas is treated wastewater.

Indirect wastewater reuse is neither new or unusual. It is not unusual for one community to dump partially treated or even untreated waste water into a river that is used as a source of water supply by downstream communities. Neither is it unusual for communities to rely heavily on ground water as a source of supply while at the same time relying on septic tanks or cesspools for wastewater disposal. The effluent from such disposal systems is only partially purified before entering the aquifers that provide water supply.

The dilution of wastewater dumped into a river, the chemical and biological reactions that take place as the water travels downstream, and the filtering of septic tank effluent through layers of soil, provide some natural purification. This treatment is, however, haphazard and does not guarantee that the water is entirely safe to use. The fact that more public health problems have not resulted from this practice is due more to good luck than to good planning.

Indirect use of wastewater can be made safe by employing carefully controlled and planned methods such as advanced wastewater treatment (AWT) plants or land treatment of wastewater.

AWT plants whether using biological or chemical-physical processes, can produce effluent that is eminently suitable for indirect water supply use. The effluent from an AWT plant can be safely discharged into a stream or surface water body that is used as a water supply source. While the emphasis and interest in AWT plants has in the past centered on their role as a pollution control tool, their usefulness as a viable source of water supply cannot be overlooked.

Land treatment is another method of indirectly using wastewater for water supply. In this method, treated wastewater is applied on the land in an even and controlled manner, and the land itself becomes a treatment and filtering medium. Thus the groundwater is recharged with clean water. This method requires substantial tracts of suitable land that may be very costly and require extensive periods of time to acquire. Land treatment can also be a means to complement land use planning objectives by providing open green space and improving agricultural yields through its irrigation and fertilization benefits.

While deliberate indirect reuse of wastewater may be possible in a short time, direct reuse is another matter. Direct reuse, that is, putting treated wastewater directly into a water supply system, involves the construction of AWT plants to treat wastewater to such a high degree of purity that it would be potable.

Direct use of AWT effluent has not been practiced in this country and is barely advanced beyond the experimental pilot plant stage here. One city in South Africa, however, has used AWT effluent as a direct source of water supply, but the method cannot yet be accepted as fully proven for general application.

Virus contamination and build up of dissolved solids present problems in dealing with direct reuse. Also, since the AWT plant would be connected directly with the water supply system, there would be no time lag in which to detect and correct any malfunction in the treatment process. Therefore, the highest degree of reliability is required. Until these problems, as well as opposition because of the general attitude toward direct reuse are overcome, this method of water supply must be deferred to the somewhat distant future.

Salt Water

The final potential source of additional water to meet growing needs is salt water. Desalting is a technically feasible option, but its application is

TREATED WASTEWATER USED FOR SPRAY IRRIGATION limited by both energy demands and the high costs of building and running such a plant. Desalting plants are large industrial complexes that can be expected to run the gauntlet of social and aesthetic problems usually associated with large industrial installations. Desalting also produces large quantities of a waste product, hot brine, that must be disposed of in an acceptable manner.

Existing institutional and legal frameworks can generally implement this method to increase supplies, especially in areas where coastal industrial complexes already exist. However, the high cost and relatively exotic nature of this technology probably preclude its quick implementation. Desalting is expensive in comparison with other sources of potable water.

Safe Yield

The safe yield of a water supply system is that amount of fresh water, expressed as a rate of flow, that can be continuously supplied during a specified drought. The worst drought of record is being used as the basis for planning in the NEWS Study, and in most sections of the Northeast this is the drought of the early 1960's. Safe yield can be increased by providing storage in manmade reservoirs or developed from the natural storage areas of lakes, aquifers and estuaries. Yield can also be developed from water which is immediately at hand flowing by in a river or from converted wastewater and salt water.

Safe yield for each new supply source is briefly defined as follows:

Systems Improvements — Safe yield is the expected incremental amount of supply improvement under drought conditions expressed as a rate of flow.

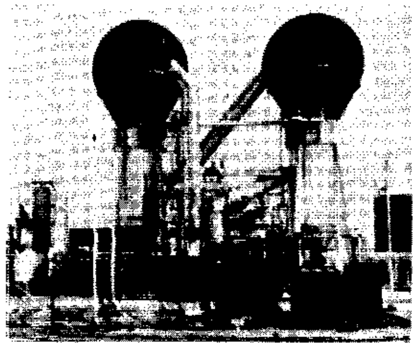
Surface Water — Safe yield is the lowest natural streamflow supplemented by storage releases that can be maintained continuously for the duration of the design drought. Safe yield may be limited by the size of intakes or treatment facilities.

Ground Water — Safe yield is the maximum draft that could be continuously supplied by pumping on a long term basis during a drought. It is theoretically the natural recharge less losses and outflows from the aquifer.

Wastewater — Safe yield is the amount of the source available, less losses in the treatment and recovery process.

Salt Water — Safe yield is limited only by intake and treatment facilities.

As the demand for water approaches the safe yield of a water supply system, greater efficiency must be used in the day to day operation of an "immediately at hand" system as opposed to operation of a "storage" system. Until a storage system is either empty or almost empty, it can



DESALTING PLANT

temporarily meet cyclical demands higher than designed for by drawing on stored reserves, since demands will have the tendency to average out during cyclical periods, of lower than average use. This flexibility is not inherent in a system that relies on water immediately at hand. If a river intake, flow or water treatment plant are not large enough, demand simply cannot be met. If this happens, resultant pressure drops can suck contaminants back into the water lines causing public health problems, and random parts of the water system will lose fire fighting capability.

The New York and Eastern Massachusetts-Rhode Island Metropolitan areas rely heavily on providing safe yield through storage, while the Washington Metropolitan Area relies primarily on water immediately at hand in the Potomac River. Water supply programs for the Washington Metropolitan Area, therefore, must be able to deal with short duration peak deficits during a drought as well as with the longer term overall deficit that develops for an entire drought period. The water supply programs for the Washington Area shown in chapter 6 are therefore based on deficits both for a long drought period over 30 days, and short term peak deficits for various time periods less than 30 days. On the other hand, programs for the New York and Eastern Massachusetts-Rhode Island areas shown in Chapters 7 and 8 are based only on deficits for a long term drought period.

Summary

System improvements, surface, ground, waste and salt water, then, are the sources that can be tapped to increase water supplies to meet demand in the three most critical areas. Each has its drawbacks and its advantages. Some sources are readily accessible, some are distant; some may be developed quickly, others will require long lead times. Some methods are costly, others less expensive. Some methods are proven, others need work to resolve their technical problems.

Each source, each method, will have its opponents and supporters, but if the demand for water is to be met in the three most critical areas of the Northeast, each and every source and method must be weighed against the consequences of not meeting demand.

CHAPTER 5: WATER SUPPLY AND OTHER PLANNING OBJECTIVES

Water is so important to our standard of living, the population is so dependent on it, that any decision involving water attracts attention from considerable numbers of people. Each person who becomes involved in the decision making process, no matter how informally, brings with him a slightly different viewpoint on which important considerations must be taken into account in that decision making process. These apparently conflicting viewpoints are often differences in emphasis only. For instance, one person may feel that the cost of a water supply project should be the determining factor in decision making. Another may agree that cost is important, but that the most vital consideration should be the reliability of the project to meet demands, and so forth.

In other cases, the difference of opinion over what should be the determining factor in selecting a source of additional supply, or a method for tapping that source, is sharp and apparently not reconcilable. A person who thinks cost should be the determining factor may face a head-on collision with another who feels that environmental quality should be the determining factor, regardless of the cost.

Such differences of opinion over what should be key factors in decision making must be considered in drawing up alternative solutions to water supply problems. It is presumed, as stated earlier, that the water supply demands of the three most critical areas will be met, but to present solutions that simply meet that goal conveniently or expeditiously, or in the most technologically feasible manner, would be to ignore the additional considerations that figure prominently in local decision makers' thinking.

In discussing the NEWS Study work with individuals in the three most critical areas, some uniformity of additional considerations was found. Most local officials mentioned low risk, limited cost, environmental impact, control of growth, and a regional focus as being vital considerations that officials and interested citizens would like to consider while meeting water supply demands. In addition to provision of an adequate water supply the following planning objectives were considered. The first four are described in Chapter 1 and refined definitions are given here.

1. *Reliability:* the ability to assure adequate quantity and quality of water supplies during conditions of severe drought.
2. *Flexibility:* the capability of being altered to efficiently accommodate future changes in projected water supply demands, and economic, environmental, social and technological considerations.
3. *Timeliness:* the capability of being implemented in time to meet water supply and other needs and to provide for orderly development of projects to meet additional water supply demands in the future.
4. *Equity:* the ability to provide for the equitable distribution of natural resources and distribute in a reasonable and logical manner the economic, social and environmental costs of providing adequate water supplies, as well as to compensate equitably those who relinquish water or land rights to meet the water demands of others.
5. *Cost:* meeting of water demands at the least monetary costs, considering both capital investments and operation and maintenance expenditures.
6. *Environmental Quality:* maintenance or enhancement of existing conditions as a result of the impact of a project.
7. *Regional Focus:* use of water from a single source over as wide an area of need as is efficient.
8. *Growth Control:* tendency of water supply programs or projects to complement local plans to influence the rate and/or distribution of population growth in an area.

Regional programs to meet the water supply demands for each of the three most critical areas are presented in this report. Each combination of projects will meet the demand for water and is also designed with consideration for local planning objectives. Different local planning objectives will consequently be met to greater or lesser degrees among the alternative regional water supply programs.

Decision Making

To simplify the comparison of different projects and combinations of projects, they are presented in the form of decision trees for each of the three most critical areas. Each branch of each decision tree illustrates one of the possible means to meet the ultimate goal of supplying sufficient water to meet demand, and at the same time complement or partially satisfy one or more other objectives of the area.

It should be noted that, in comparing the programs on decision tree branches, one objective can generally be satisfied only at the expense of others. Projects designed for least cost, for instance, might be found less satisfactory for other objectives such as environmental impact or flexibility. A program to emphasize those objectives would amost certainly be more costly.

Despite the large numbers of technically feasible projects available in each of the three most critical areas, it is not possible to satisfy all objectives in each area with one water supply program nor has an objective measure of success been devised.

The next three chapters of this report will present sources, projects and illustrative combinations of projects. No attempt is intended to advocate any particular project or combination of projects, or any sequence in which they should be built. The purpose here is to lay out the various alternatives so that the people of the three most critical areas might more easily see the choice of actions available to them.

Cost Sharing

An important consideration for any regional program for water supply must be the financial and cost sharing arrangements that might be used to bring it into being.

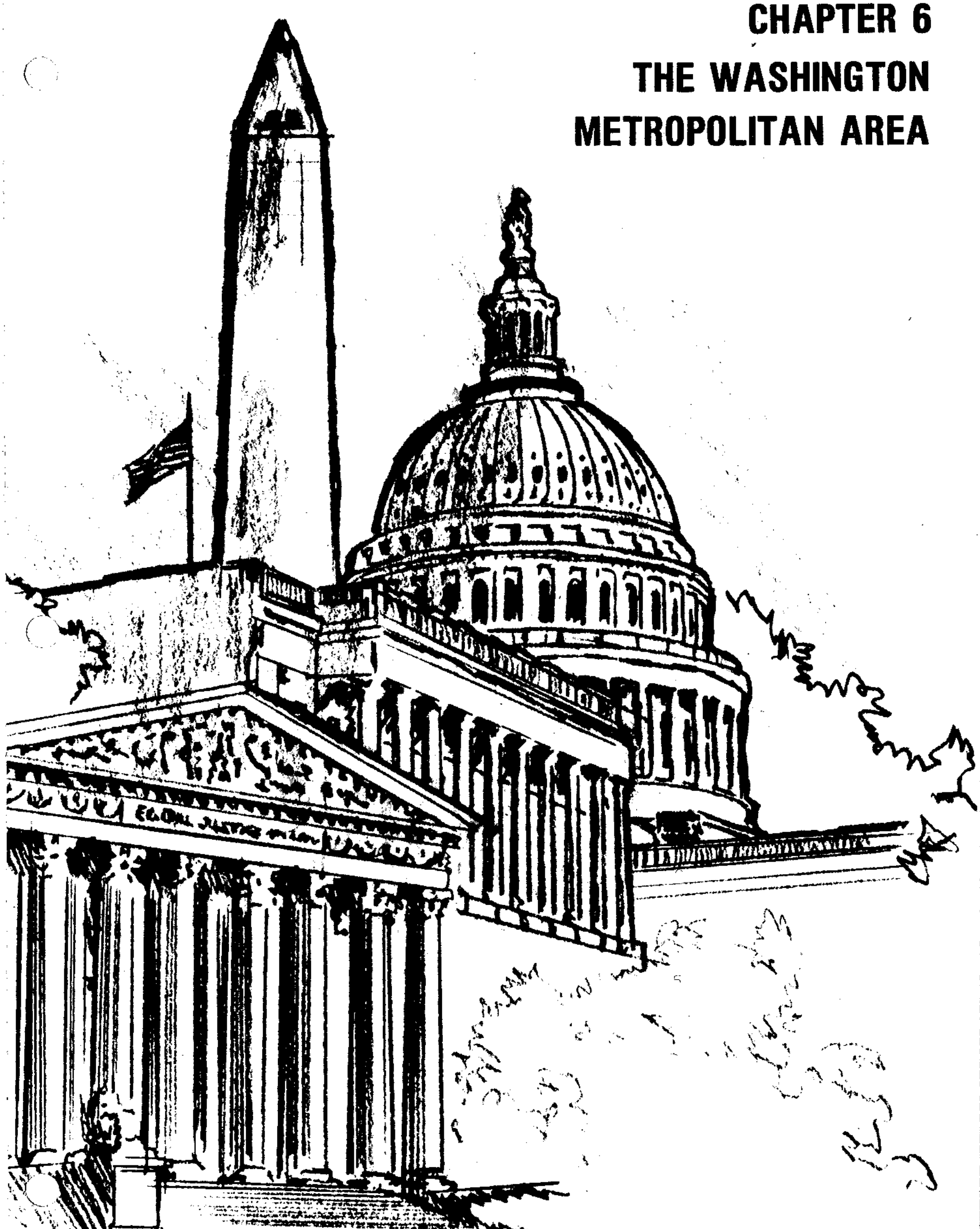
For projects proposed for authorization under the NEWS authority, it has been considered equitable for local interests to assume operation and maintenance and to repay to the United States over a 50-year period, in accordance with the 1958 Water Supply Act, all construction costs expended by the Federal government with interest at the rate prescribed by the Water Resources Council for water supply projects.

In the *Interim Report,* costs based on Federal financing were compared with costs based on financing at local rates of interest and amortized over the 35-year period normal to local governments. The purpose was to assist local officials to determine whether there were any near term regional projects which they wished to have considered for detailed pre-authorization study by the Corps of Engineers. In only one area, the NYMA, was a request for such detailed investigation made. The resulting report on the Hudson River Project is contained in the Appendix to this *Summary Report.*

Energy

In view of the recent energy crisis and the critically low generating capacity reserve in much of the Northeast, energy requirements for the operation of projects have been considered. As a rule, systems which deliver raw water by gravity require less energy than systems which deliver water by extensive water treatment and pumping.

CHAPTER 6
THE WASHINGTON METROPOLITAN AREA



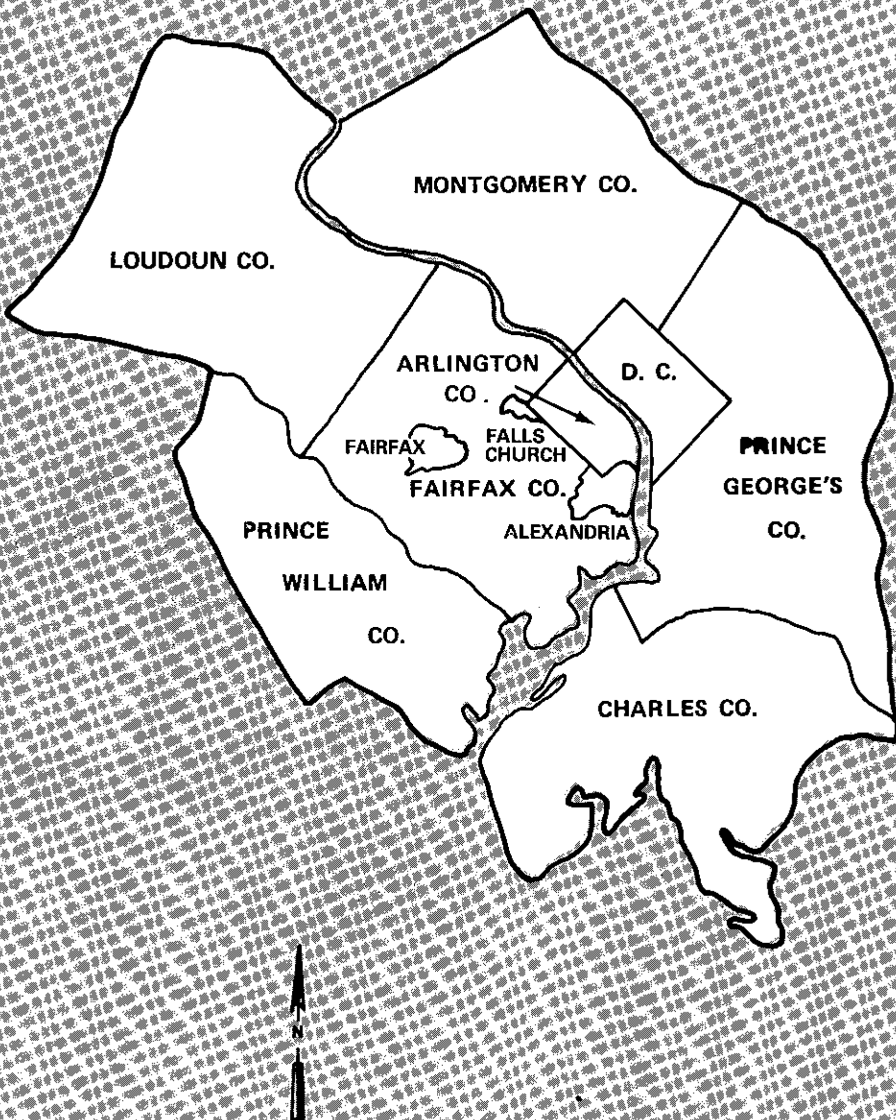


FIGURE 6-1. WASHINGTON METROPOLITAN STUDY AREA

CHAPTER 6: THE WASHINGTON METROPOLITAN AREA (WMA)

BACKGROUND

Recommendations to meet the immediate water supply needs of the Washington Metropolitan Area (WMA) have already been made to the Congress as part of the NEWS Study. The recommendations are contained in a report, "Potomac River Basin Water Supply—An Interim Report," dated April, 1973.

These recommendations are:

• Construction of the Verona Dam and Lake in Virginia and Sixes Bridge Dam and Lake in Maryland to meet the near-term demands with the proven technique of reservoirs.

• The construction of a pilot estuarine water treatment plant to determine the technical feasibility of full scale use of the estuary for water supply, and to investigate the public health risks related to use of the estuary.

As a result of these recommendations Public Law 93-251 authorized the construction of the pilot estuarine treatment plant and Phase I of advanced engineering and design of Verona Dam and Lake and Sixes Bridge Dam and Lake. Further authorization of Sixes Bridge Dam Project is conditioned upon completion of the Metropolitan Washington Area (MWA) Water Supply Study also authorized in Public Law 93-251.

These steps and construction of Bloomington Dam and Lake expected to be completed in 1980 or 1981, constitute the first actions to solve the more immediate water supply problems of the WMA. However, this chapter presents alternatives to all projects except construction of Bloomington Lake.

The alternatives presented have been based on a number of other NEWS studies done for the WMA and referenced in the Annotated List of NEWS Reports. Much of this work was summarized in a staff report issued in April, 1974 and circulated in the Washington Area. Recent public feedback and technical studies have provided the basis upon which a further consolidation of these alternatives has been made. The "NEWS Washington Metropolitan Area Water Supply Study" report was issued in November, 1975 and provides a basis upon which the ongoing WMA Water Supply Study can proceed.

AREA PROFILE

The Washington Metropolitan Area lies primarily within the Potomac River Basin with its eastern section in the much smaller Patuxent River Basin. The WMA encompasses land and water in the states of Maryland and Virginia and the District of Columbia. It covers 2800 square miles and consists of Montgomery, Prince George's and Charles Counties in Maryland; the District of Columbia; the Cities of Falls Church, Fairfax, and Alexandria, and the Counties of Loudoun, Fairfax, Prince William and Arlington in Virginia (see Figure 6-1).

The WMA deserves special consideration because it is the Nation's Capital, a regional center, and because of the magnitude of its water supply problems. This area is designated as a Standard Metropolitan Statistical Area (SMSA) for the purposes of census data collection. The 1970 population of about three million represents a 39 percent increase over the 1960 level and makes Metropolitan Washington the seventh most populous SMSA in the country. Population projections for the area show 3.7 million persons by 1980, and 6.8 million persons by 2020 (see Table 6-1).

WATER DEMANDS

Demands for water in the WMA are based on projections, through 1992, by the Metropolitan Washington Council of Governments (COG). They were modified by adding Charles County, extension to 2020 and downward adjustment of 1 mgd per year for water saving devices assumed to become required by local building codes in the future. Resulting regional demands are shown in Table 6-1.

A fairly stable per capita demand for water is expected for the WMA between 1980 and 2020. This is due to two factors: first, little increase is projected for water using industries; second, it is a high income area with a resulting saturation of domestic water-using appliances. Consequently, the increase in per capita use expected in many areas of the country due to increased use of such appliances is not expected in the WMA.

AVAILABLE WATER

A number of raw drinking water sources were considered for the WMA. However, the costs and legal complications involved with major inter basin transfer projects, such as from the Susquehanna or Rappahanock, indicated that the relatively undeveloped nearby sources should be considered first.

Potomac River

The largest single water resource within the Washington Metropolitan Area, the Potomac River, has an average discharge at Point of Rocks of 5,975 mgd. Beginning in the mountains of West Virginia, it flows north in Maryland, and then generally southeasterly toward Washington, D.C., for 248 miles, to Little Falls, becoming

CHAPTER 6: THE WASHINGTON METROPOLITAN AREA (WMA)

BACKGROUND

Recommendations to meet the immediate water supply needs of the Washington Metropolitan Area (WMA) have already been made to the Congress as part of the NEWS Study. The recommendations are contained in a report, "Potomac River Basin Water Supply—An Interim Report," dated April, 1973.

These recommendations are:

- Construction of the Verona Dam and Lake in Virginia and Sixes Bridge Dam and Lake in Maryland to meet the near-term demands with the proven technique of reservoirs.
- The construction of a pilot estuarine water treatment plant to determine the technical feasibility of full scale use of the estuary for water supply, and to investigate the public health risks related to use of the estuary.

As a result of these recommendations Public Law 93-251 authorized the construction of the pilot estuarine treatment plant and Phase I of advanced engineering and design of Verona Dam and Lake and Sixes Bridge Dam and Lake. Further authorization of Sixes Bridge Dam Project is conditioned upon completion of the Metropolitan Washington Area (MWA) Water Supply Study also authorized in Public Law 93-251.

These steps and construction of Bloomington Dam and Lake expected to be completed in 1980 or 1981, constitute the first actions to solve the more immediate water supply problems of the WMA. However, this chapter presents alternatives to all projects except construction of Bloomington Lake.

The alternatives presented have been based on a number of other NEWS studies done for the WMA and referenced in the Annotated List of NEWS Reports. Much of this work was summarized in a staff report issued in April, 1974 and circulated in the Washington Area. Recent public feedback and technical studies have provided the basis upon which a further consolidation of these alternatives has been made. The "NEWS Washington Metropolitan Area Water Supply Study" report was issued in November, 1975 and provides a basis upon which the ongoing WMA Water Supply Study can proceed.

AREA PROFILE

The Washington Metropolitan Area lies primarily within the Potomac River Basin with its eastern section in the much smaller Patuxent River Basin. The WMA encompasses land and water in the states of Maryland and Virginia and the District of Columbia. It covers 2800 square miles and consists of Montgomery, Prince George's and Charles Counties in Maryland; the District of Columbia; the Cities of Falls Church, Fairfax, and Alexandria, and the Counties of Loudoun, Fairfax, Prince William and Arlington in Virginia (see Figure 6-1).

The WMA deserves special consideration because it is the Nation's Capital, a regional center, and because of the magnitude of its water supply problems. This area is designated as a Standard Metropolitan Statistical Area (SMSA) for the purposes of census data collection. The 1970 population of about three million represents a 39 percent increase over the 1960 level and makes Metropolitan Washington the seventh most populous SMSA in the country. Population projections for the area show 3.7 million persons by 1980, and 6.8 million persons by 2020 (see Table 6-1).

WATER DEMANDS

Demands for water in the WMA are based on projections, through 1992, by the Metropolitan Washington Council of Governments (COG). They were modified by adding Charles County, extension to 2020 and downward adjustment of 1 mgd per year for water saving devices assumed to become required by local building codes in the future. Resulting regional demands are shown in Table 6-1.

A fairly stable per capita demand for water is expected for the WMA between 1980 and 2020. This is due to two factors: first, little increase is projected for water using industries; second, it is a high income area with a resulting saturation of domestic water-using appliances. Consequently, the increase in per capita use expected in many areas of the country due to increased use of such appliances is not expected in the WMA.

AVAILABLE WATER

A number of raw drinking water sources were considered for the WMA. However, the costs and legal complications involved with major inter basin transfer projects, such as from the Susquehanna or Rappahanock, indicated that the relatively undeveloped nearby sources should be considered first.

Potomac River

The largest single water resource within the Washington Metropolitan Area, the Potomac River, has an average discharge at Point of Rocks of 5,975 mgd. Beginning in the mountains of West Virginia, it flows north in Maryland, and then generally southeasterly toward Washington, D.C., for 248 miles, to Little Falls, becoming

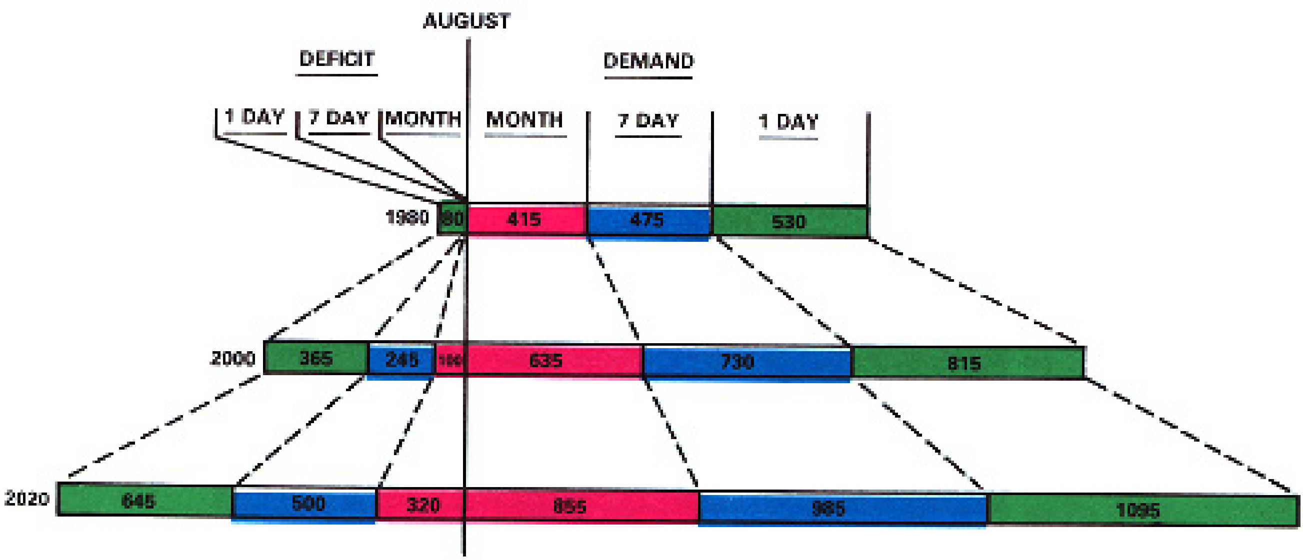
TABLE 6-2. POTOMAC RIVER FLOWS, DEMANDS AND DEFICIT[1]

MONTH	PERIOD	1980 Demand[2] (MGD)	1980 Flow[3] (MGD)	1980 Deficit (MGD)	2000 Demand[2] (MGD)	2000 Flow[3] (MGD)	2000 Deficit (MGD)	2020 Demand[2] (MGD)	2020 Flow[3] (MGD)	2020 Deficit (MGD)
July	Month	420	670	–	650	670	–	880	670	210
	7-day	450	470	–	695	470	225	940	470	470
	1-day	500	445	55	770	445	325	1040	445	595
Aug.	Month	415	535	–	635	535	100	855	535	320
	7-day	475	485	–	730	485	245	985	485	500
	1-day	530	450	80	815	450	365	1095	450	645
Sept.	Month	390	575	–	605	575	30	815	575	240
	7-day	425	530	–	655	530	125	890	530	360
	1-day	450	495	–	700	495	205	945	495	450
Oct.	Month	350	490	–	545	490	55	735	490	245
	7-day	360	460	–	560	460	100	760	460	300
	1-day	380	435	–	590	435	155	795	435	360
Nov.	Month	335	520	–	515	520	–	700	520	180
	7-day	345	435	–	540	435	105	730	435	295
	1-day	355	415	–	555	415	140	750	415	335

[1] Includes that portion of the WMA withdrawing from the Potomac River, presently and in the future.

[2] **DEMAND** — Month figures are monthly averages. A seven day figure is the maximum average demand of any seven (7) consecutive days in the month. A one-day figure is the highest one-day demand that month. Does not include Non-Potomac River demands; includes a one (1) MGD incremental reduction per year due to water saving devices.

[3] **FLOW** — Month figures are monthly averages. A seven-day figure is the minimum average flow of any seven (7) consecutive days in the month. A one-day figure is the lowest one day flow of that month. Includes Potomac River flows at Point of Rocks, Bloomington Dam and Lake coming on line in 1980 and making an allowance of 100 m.g.d. to be left instream for flow into the estuary.



Ground Water

There are two regions within the study area from which ground water supplies are available, the Hagerstown Valley and the Coastal Plains. The range of yields from individual wells varies, and the safe yield of each well field has not been determined.

OTHER FACTORS

Water treatment capability and the capacity of the existing water supply distribution system are two factors that, in addition to safe yield, limit Washington's water supplies. Existing system capacities will not be adequate for future demands. Expansions, however, have been planned by the major utilities.

WATER SUPPLY PROGRAMS

Alternative water supply programs to meet the WMA demands have been formulated. All programs satisfy the fundamental water supply objective and complement other planning objectives such as reliability, flexibility, economy and environmental quality.

FIGURE 6-2 MONTHLY AVERAGE SUPPLY

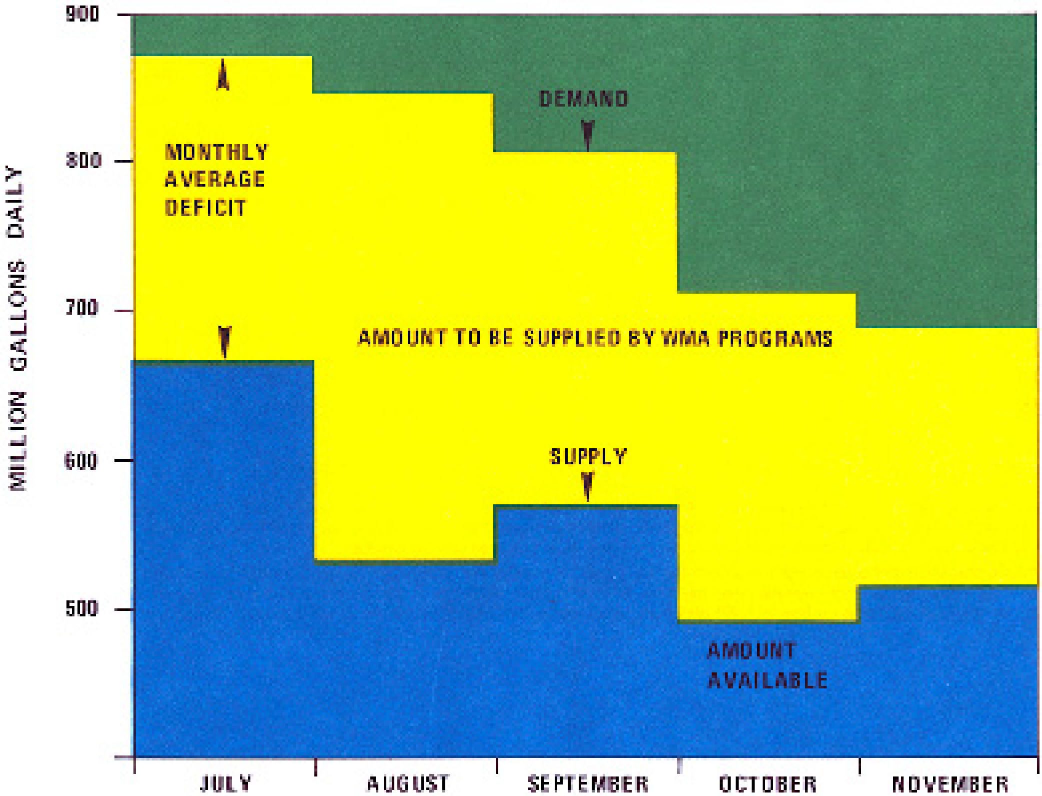
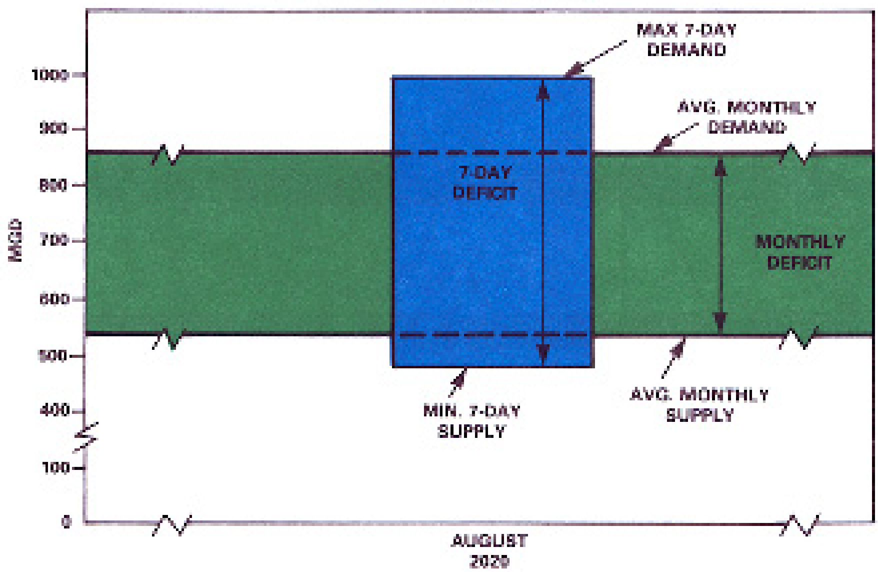


FIGURE 6-3. COMPARISON OF MONTHLY AND 7-DAY SUPPLIES & DEMANDS IN 2020



The lack of storage in the basin means that the portion of WMA demands being met by river withdrawals is very sensitive to the wide fluctuation of Potomac River discharges. This sensitivity is compounded by seasonal variation in demand. If highest demands occur at times of lowest flow, deficits will be large. The alternatives for the WMA have been formulated in such a way that some risk exists if highest demand occurs during times of lowest flow. Historically this has not occurred and public feedback indicates that many individuals in the area are willing to accept this risk.

Demands were projected to vary by month in a constant manner with July being the month of highest use. Supply was projected similarly with the lowest flows occurring in October. On this basis the critical monthly deficit always occurs in August when the difference between supply and demand is the greatest. Maximum 7 day and maximum 1 day periods have been examined to determine critical peak deficits of shorter duration than a month.

Recognizing the conflicting uses for water resources, a detailed analysis of supply and demand was conducted to establish minimum project requirements to satisfy the water supply need. This analysis consists primarily of comparing supply and demand on a month by month basis to determine deficits. As much as possible, the programs were designed to eliminate monthly deficits with monthly or base load projects and seven day deficits with seven day or peaking projects. In some cases projects can be operated for both. Solution of the one day deficit problem can be more appropriately handled by the local utilities. This approach to program design will supply water to the WMA in an efficient manner consistent with other planning objectives. The programs have been arranged into decision tree branches and the timing of decisions required to place water supply projects on line in time to avert most shortages is shown in Figure 6-4.

Many of the project alternatives suggested by local interests involve new or unproven technologies. Before any of these can be implemented, their technical feasibility must be proven. Small scale pilot facilities to evaluate estuary treatment, advanced wastewater treatment (AWT) facilities, land treatment and unproven ground water aquifers are necessary. The pilot tests of these technologies and the necessary evaluations could delay their full scale implementation until late in the period 1990-2000. If demand is adjusted to explicitly incorporate conservation programs, Bloomington Dam and Lake can meet the monthly WMA demand through 1990. The seven day demands cannot be met by Bloomington much beyond 1980. Therefore, an additional project must be on line as soon as possible unless the people of the region are willing to accept an increased risk of having a water supply deficit.

Consequently, the choice to be made in the WMA is whether to: 1) Use proven technologies such as raw water interconnections, Verona and Sixes Bridge Dam and Lake and local impoundments; or 2) accept the risk of seven day supply deficits until programs of land treatment, estuary treatment, AWT plants, and ground water aquifers are demonstrated to be viable.

Branches 1, 2 and 3, as shown in Figure 6-5, include projects using unproven technologies which could not be expected to become operational until late in the 1990-2000 period. Projects in Branches 4 and 5 are based solely on proven technologies and could come on line early in the 1990-2000 period.

The following is a list of projects considered viable for the WMA and used as the basis for selection of components of the regional programs.

- **Upstream Reservoirs.** Verona Dam and Lake would be located near Staunton, Virginia and could supply 190 mgd as required for a particular program. The 3,900 acre project would cost an estimated $55.3 million exclusive of recreational development costs. Sixes Bridge Dam and Lake, near Sixes Bridge, Maryland, could supply 85 to 90 mgd as required at an estimated cost of $33.7 million for water supply. Both projects would be operated to increase the average monthly base flow of the Potomac.

- **Estuary Treatment Plant.** Indirect or direct reuse of water withdrawn from the upper portion of the Potomac estuary could be accomplished after advanced treatment. Two systems are being considered. The first is a river mix (indirect use) system that would pump between 100 mgd and 200 mgd of treated water 35 river miles upstream of the Washington, D.C. intakes on the Potomac River to augment existing stream flows. The second would be a plant mix (direct use) system that could pump between 50 mgd and 100 mgd of treated, estuary water to an existing water supply plant and mix it with plant water. Construction of a pilot plant to provide additional data was initiated in 1977 by the Corps.

- **Local Water Impoundments Within the WMA.** Local reservoirs could be constructed on Potomac River tributaries and filled by pumping from the Potomac River during periods with higher than normal flows. Releases would be made to augment the Potomac during periods of low flow. Several potential sites are located in Loudoun and Montgomery Counties. Such impoundments could supply from 90 to 500 mgd and could be used to provide peaking water to meet seven day and monthly demands. Catoctin, Goose Creek and Little Monocacy projects are

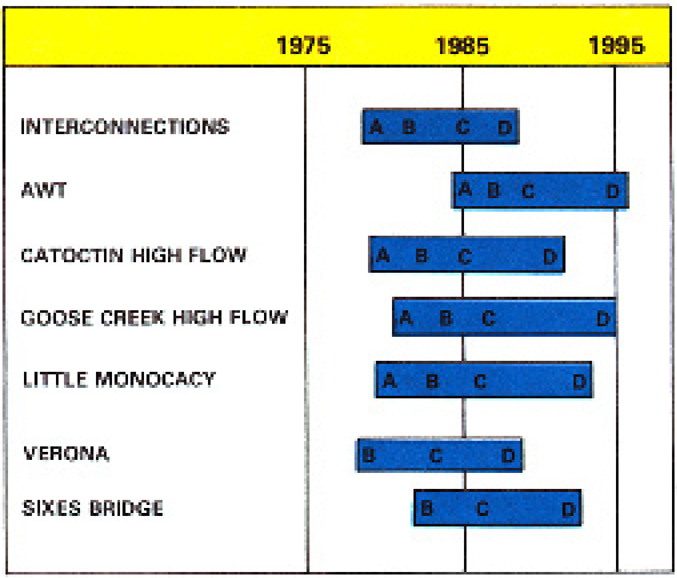


FIG. 6-4. DECISION TIMING FOR INITIAL PROJECTS WMA

LEGEND
A—PROJECT APPROVAL
B—FUNDING FOR ENGINEERING DESIGN
C—FUNDING FOR CONSTRUCTION
D—ON LINE

presented in this report to illustrate this type of project.

Since the completion of the original study in November 1975, reaches in both Catoctin and Goose Creeks on which considered sites were located have been designated as Wild and Scenic Rivers by the State of Virginia. The Catoctin Creek designation includes 16 miles in Loudoun County between Waterford and the Potomac River, and the Goose Creek designation lies between the confluence of the Creek with the Potomac River and the Route 50 Bridge crossing in Loudoun County. These reaches are protected under State Law which prevents construction without specific approval of the Legislature. The Catoctin and Goose Creek projects lie within these designated reaches.

However, both projects have been retained in this report as illustrative of the type of local impoundments required and other sites would be equally effective.

• **Interconnections.** Water would be pumped from the Potomac River during high flow periods to fill existing reservoirs that would, in turn, augment the river during low flow periods. Two existing reservoir systems have been considered at Rocky Gorge Reservoir on the Patuxent River and Occoquan Reservoir on Occoquan Creek. Yield from these interconnections would range from 100 mgd to 265 mgd and could provide water for seven day demands.

• **Wells.** Two ground water areas were considered, the coastal plain area in Charles and Prince George's Counties in Maryland, which would yield an estimated 100 mgd; and the Hagerstown Valley area of Maryland which could yield an estimated 50 mgd to augment the river during periods of low flow.

• **Advanced Wastewater Treatment.** Through the use of advanced wastewater treatment plants (AWT), wastewater could be treated to stream quality standards. One AWT system under consideration in this study would take effluent directly from the Blue Plains Wastewater Treatment Plant, treat it further, and discharge it to the Potomac River 35 miles upstream of Washington, D.C. Other AWTs could be located in Loudoun and Montgomery Counties to treat wastewater generated by future growth in these areas. Yields are estimated to range from 35 mgd to 220 mgd.

• **Land Treatment of Wastewater.** Secondary wastewater treatment plant effluent would be sprayed on land, and through natural biological and physical processes it would be brought to stream quality standards. The water would be recovered through natural run-off into the Potomac. A site under consideration is in Loudoun County. The estimated yield of this project is 25 mgd although 50 mgd would be required for spraying, the difference being lost due to evapotranspiration.

- **Emergency Restrictions.** Restrictions to limit specific water uses during temporary periods of shortage would be the only means available to avert complete system shutdowns in the time period before proposed projects could be brought on line, or in all periods if water supply programs are adopted for the WMA which do not provide enough additional water to meet projected demands. Restrictions would be voluntary or mandatory depending upon the severity of each emergency as it occurred, or as determined to be necessary by the implementing local government. In all programs developed for this report, restrictions have been included. In some programs restrictions of up to 195 mgd are required to meet program deficits.

DECISION TIMING

The timing involved for implementation of each project was an important factor when projects were selected for inclusion in a plan. The schedules for projects that can come on line by 2000 are shown in Figure 6-4.

Interconnections would be the first projects on line in Branches 1A, 1B, and 4A and would take about 10 years to implement. Initial indications as to the effects of mixing Potomac River water with the water in existing reservoirs are favorable, but detailed impacts of the interconnections would have to be carefully studied before construction. AWT plants, the first projects to come on-line in Programs 2 and 3, would take about 12 years to implement after their acceptability as potable water sources has been demonstrated. The Catoctin High Flow Skimming Impoundment in Virginia would be the first project to come on-line in Program 4B and would take about 14 years to implement. Goose Creek High Flow Skimming Impoundment is the only project needed after construction of the Bloomington Project to meet monthly water demands until 2020 in Program 4C. About 15 years would be needed to implement the project. Verona Dam and Lake would be the first project to come on line in Programs 5A and 5B. The project is located in an area which is becoming increasingly urbanized and would therefore require careful land use planning before state and local approval could be obtained.

Verona Dam and Lake Project has already received state and Federal approval through the initial design stage. Additional Federal and state approval is required prior to construction. The project could not be operational in time to eliminate the risk of seven day shortages. In addition, the estimated 27 days it takes for water to travel from the dam to the area of use makes it inefficient to use as a seven day source.

PLANNING ASSUMPTIONS

The following assumptions were made to formulate the alternative decision tree programs shown on Figure 6-5:

1. Water supplies will be provided to meet projected average monthly demands. Demand projections have been reduced to reflect use reductions through water saving fixtures and appliances of 1 mgd per year after 1975, for a total of 45 mgd by 2020. WMA demand was then disaggregated into Potomac and non-Potomac demands. The programs compare Potomac supplies with Potomac demands.

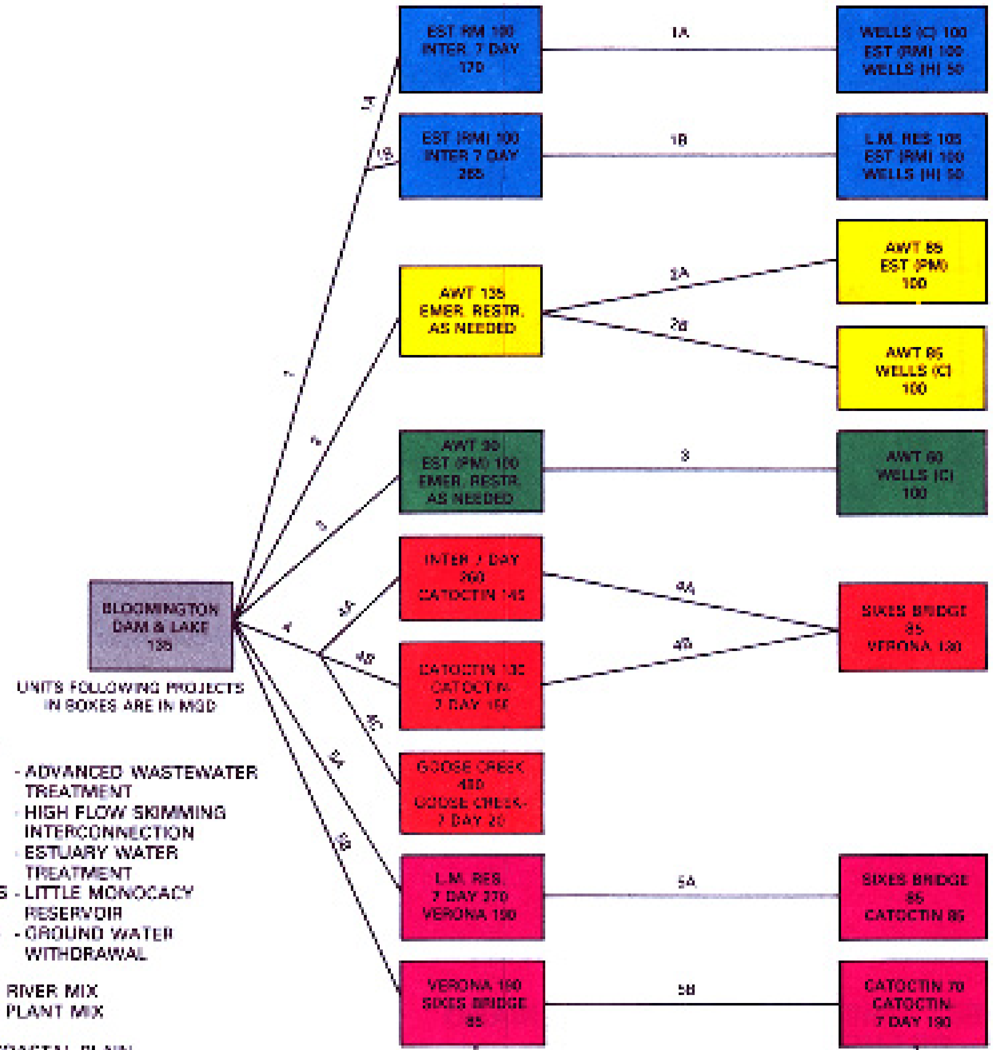
2. Short term peak deficits between 7 and 30 days duration are alleviated with peaking projects which supply large quantities of water for short periods or through emergency water restrictions that reduce the short term peak demand. Application of restrictions could reduce monthly demand to the level approximated by winter demands, when lawn watering, filling of swimming pools and similar non-essential activities are at a minimum. Emergency restrictions would be required in all branches, but were only shown in the Decision Tree (Figure 6-5) when they would be needed to meet a monthly average deficit.

3. In all programs, projects were not considered for meeting one day deficits which could be alleviated by demand reduction through emergency restrictions, by local storage provided by water utilities, by reducing the 100 mgd minimum flow into the estuary, or by using an emergency estuary intake under construction by the Corps of Engineers in 1977.

4. Yield is based on the monthly minimum safe yield of the Potomac River at Point of Rocks less 100 mgd minimum flow to the estuary.

5. Bloomington Dam and Lake, now under construction on the North Branch of the Potomac River, will be operational in the 1980 time frame.

FIGURE 6—5
DECISION TREE—WMA PROJECTS



LEGEND:
AWT - ADVANCED WASTEWATER TREATMENT
INTER - HIGH FLOW SKIMMING INTERCONNECTION
EST - ESTUARY WATER TREATMENT
LM RES - LITTLE MONOCACY RESERVOIR
WELLS - GROUND WATER WITHDRAWAL

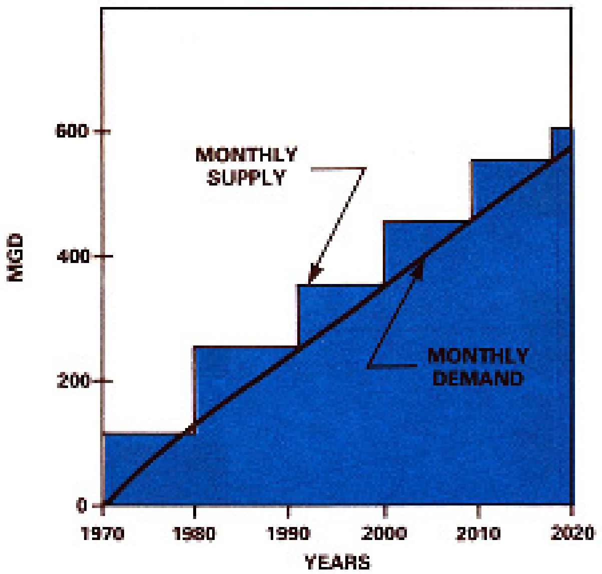
(RM) = RIVER MIX
(PM) = PLANT MIX

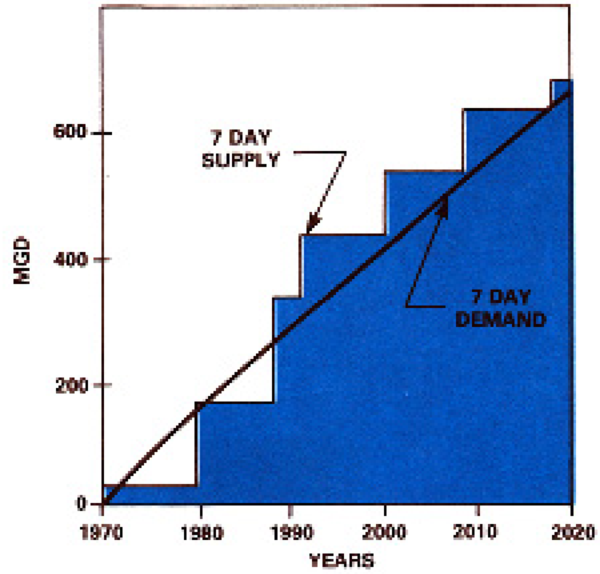
(C) = COASTAL PLAIN
(H) = HAGERSTOWN VALLEY

	Through 1980		Through 2000			Through 2020		
	Additional Demand[1] MGD		Additional Cumulative Demand (MGD)[1]			Additional Cumulative Demand (MGD)[1]		
	Month	7 Day	Month	7 Day		Month	7 Day	
	135	155	355	410		575	685	
	Additional Supply (MGD)		Cumulative Additional Supply (MGD)		Total Annual Cost (Million $)	Cumulative Additional Supply (MGD)		Total Annual Cost (Million $)
Branch	Month[2]	7 Day[3]	Month	7 Day[4]		Month	7 Day[4]	
1A	255	165	355	435	37.2	605	685	49.1
1B	255	165	355	530	40.0	610	785	46.7
2A	255	165	390	300/110	28.5	575	485/180	36.3
2B	255	165	390	300/110	28.5	575	485/180	36.8
3	255	165	445	355/55	20.4	605	515/150	28.7
4A	255	165	400	570	22.6	615	785	22.6
4B	255	165	385	450	4.9	600	665	8.7
4C	255	165	735	665	17.8	735	665	17.8
5A	255	165	445	625	8.5	615	795	13.4
5B	255	165	530	440	8.5	600	700	8.7

[1] Figures shown are August requirements.
[2] Includes current undeveloped surplus river flow of 120 m.g.d.
[3] Includes current undeveloped surplus river flow of 30 m.g.d.
[4] Number below slash indicates unmet demand, which are to be met through demand restrictions.

ADDITIONAL SUPPLY DEMAND VS. TIME BRANCH 1A - AUGUST





PROJECT TIMING AND SUPPLY, DEMAND DATA - BRANCH 1-A

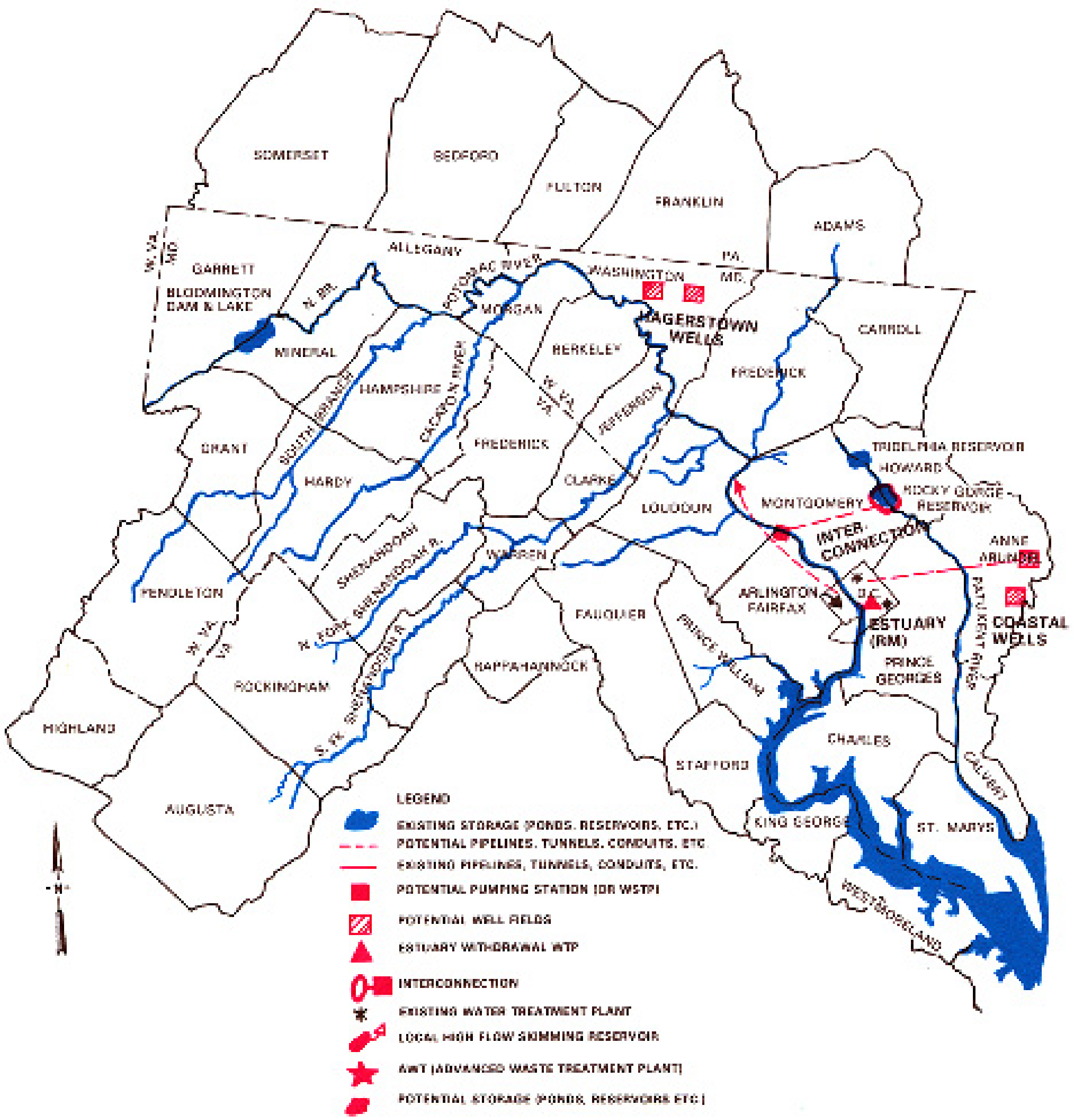
1980: BLOOMINGTON DAM AND LAKE 135 MGD

2000: ESTUARY (RM) 100 MGD; INTER (7 DAY) 170 MGD

2020: ESTUARY (RM) 100 MGD; WELLS (C) 100 MGD; WELLS (H) 50 MGD

YEAR	1970		1980		2000		2020	
	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY
ADDITIONAL DEMAND (MGD)	—	—	135	155	355	410	575	665
ADDITIONAL SUPPLY (MGD)	120	30	255	165	355	435	605	685

BRANCH 1A



BRANCH ONE — Based on a mix of proven and unproven technologies in both the earlier and later time frames.

Branch 1 is formulated to minimize health risk by delaying use of the estuary until more questions can be answered by the pilot estuary treatment plant and assuming that this can be done early enough to allow full scale implementation before 2000. In addition, it minimizes large scale, land intensive reservoir construction.

PROGRAM DESCRIPTIONS — 1A and 1B

1980 — With Bloomington Dam and Lake operating by about 1980, adequate supplies to meet monthly demands are available. Seven day deficits could occur and would be met by restrictions as needed.

2000 — Between the 1980 and 2000 time frames an interconnection routed through Montgomery County between the Potomac River and existing Patuxent Reservoirs could meet a portion of the seven day demands through 2020. In Program 1A the interconnection would supply an additional 170 mgd and in Program 1B an additional 265 mgd. To meet monthly demands for both programs, the first stage of the River Mix Estuary Treatment Plant located in Washington, D. C. would be brought on line to supply an additional 100 mgd.

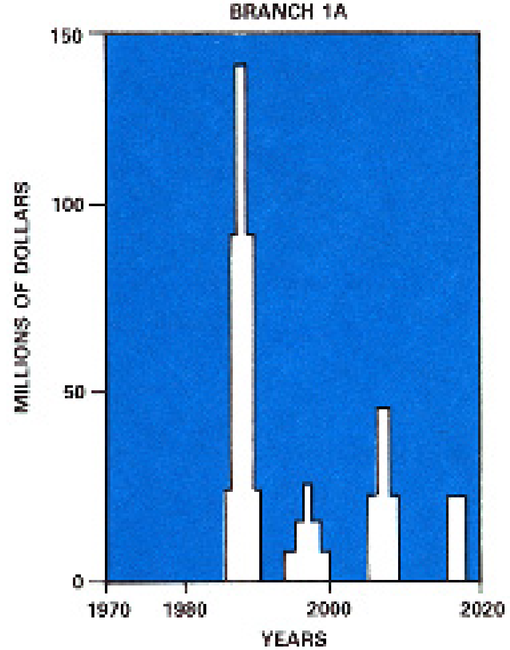
2020 — Between 2000 and 2020 in both Programs 1A and 1B, stage two of the Estuary Treatment Plant would supply an additional 100 mgd. In 1A 100 mgd would also be necessary from wells constructed on the Maryland coastal plain. Instead of wells, a high flow skimming dam and lake project, on the Little Monocacy in Montgomery County, supplying 105 mgd, would be constructed in Program 1B.

Wells constructed in the Hagerstown Valley area of Maryland would provide 50 mgd for demands in both 1A and 1B.

PROJECT DATA FOR BRANCH 1-A

Project	Yield Month MGD	Yield 7 Day MGD	Capital Cost ($ Millions)	Annual OM&R ($ Millions)	Annual Cost ($ Millions)
Bloomington	135	135			
Inter-Connection	0	170	137.5	1.10	11.2
Estuary	200	200	319.5	2.65	26.0
Wells (C)	100	100	98.9	1.05	8.3
Wells (H)	50	50	42.9	.49	3.6
Surplus	120	30	—	—	—
Total	605	685	598.8	5.29	49.1

FIRST COST REQUIREMENTS
BRANCH 1A



PROGRAM RATIONALE

An interconnection project, a river mix estuary treatment plant and two wellfield areas — one in the Coastal plain and the other in the Hagerstown Valley, are the projects selected for Program 1-A.

Seven day interconnections projects offer proven ability to meet water quality standards as well as a reliable source of water. Environmentally, they have high energy requirements, but require little land and have minimal effect on aquatic and animal life, natural habitat, vegetation, etc. Costs and benefits would be well distributed in the region. Construction would occur only close to the WMA. Although interconnections offer flexibility in the quantity of water which can be obtained, it would be desirable to build the required pipeline to its ultimate capacity because of the inefficiency involved in building a series of smaller pipelines as needed.

The river mix estuary treatment plant and wellfields provide monthly needs and complete the projects for Branch 1A. The estuary and wellfields rank high in environmental quality with the exception of the high energy requirements for operating the estuary treatment plant and for pumping estuarine water up to Dickerson, Maryland. The estuary plant could provide a large volume of water but would create water quality questions due to the uncertainty of operating an estuary plant that will always meet water standards. Wells on the other hand, may provide high quality water, but quantities remain a question due to as yet unproven yields.

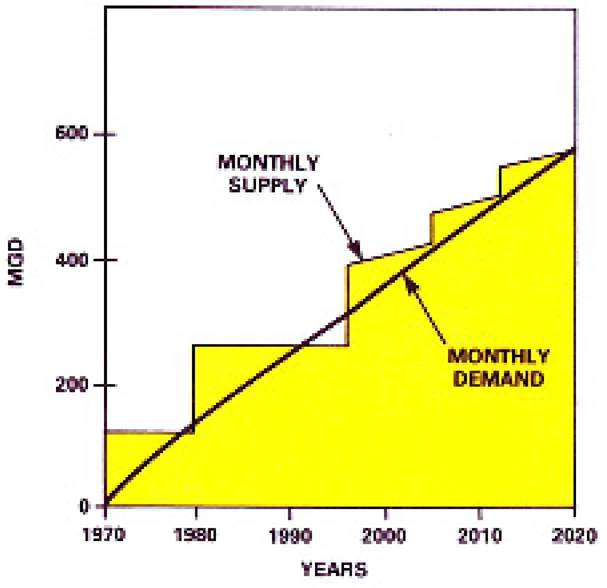
Flexibility to increase output is high in the case of wells and moderate for the estuary plant.

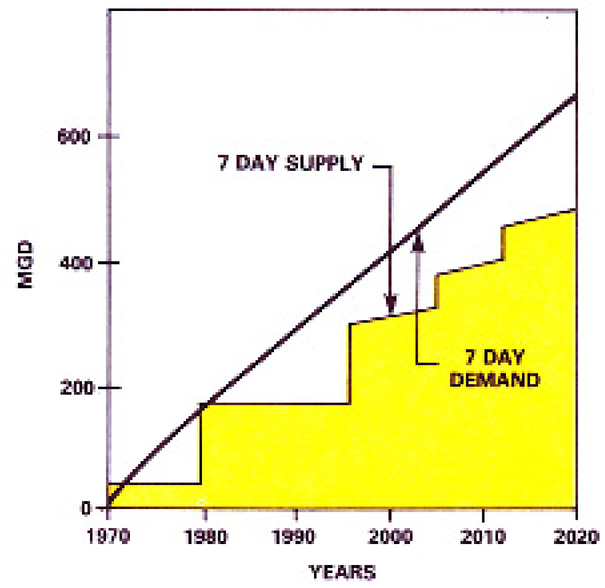
Social and economic equity, is served well by the estuary but less so by the wellfields. The river mix estuary uses local sources but the wellfields are located some distance from those who would benefit most.

With the exception of the interconnections, the projects in Program 1A rely on new or unproven technology. The potential for wells has yet to be established and uncertainty remains as to the quality of the treated estuary water in terms of sustained yield, reliability and health risks. These unproven technologies require pilot efforts to help resolve the uncertainties related to their use.

Program 1B is in most respects identical to Program 1A, except that larger interconnections would be used to provide greater seven day peaking capability and a Potomac high flow skimming project on the Little Monocacy instead of the Coastal Plain Wells. This reservoir would provide a reliable source of water of known quality. Questions could arise at the local level regarding land acquisition in Montgomery County to supply the metropolitan area, a situation common to all areas of high population density which must reach beyond their boundaries for water.

ADDITIONAL SUPPLY DEMAND VS. TIME
BRANCH 2A - AUGUST





PROJECT TIMING AND SUPPLY, DEMAND DATA
BRANCH 2A

BLOOMINGTON DAM AND LAKE 135 MGD (1980)

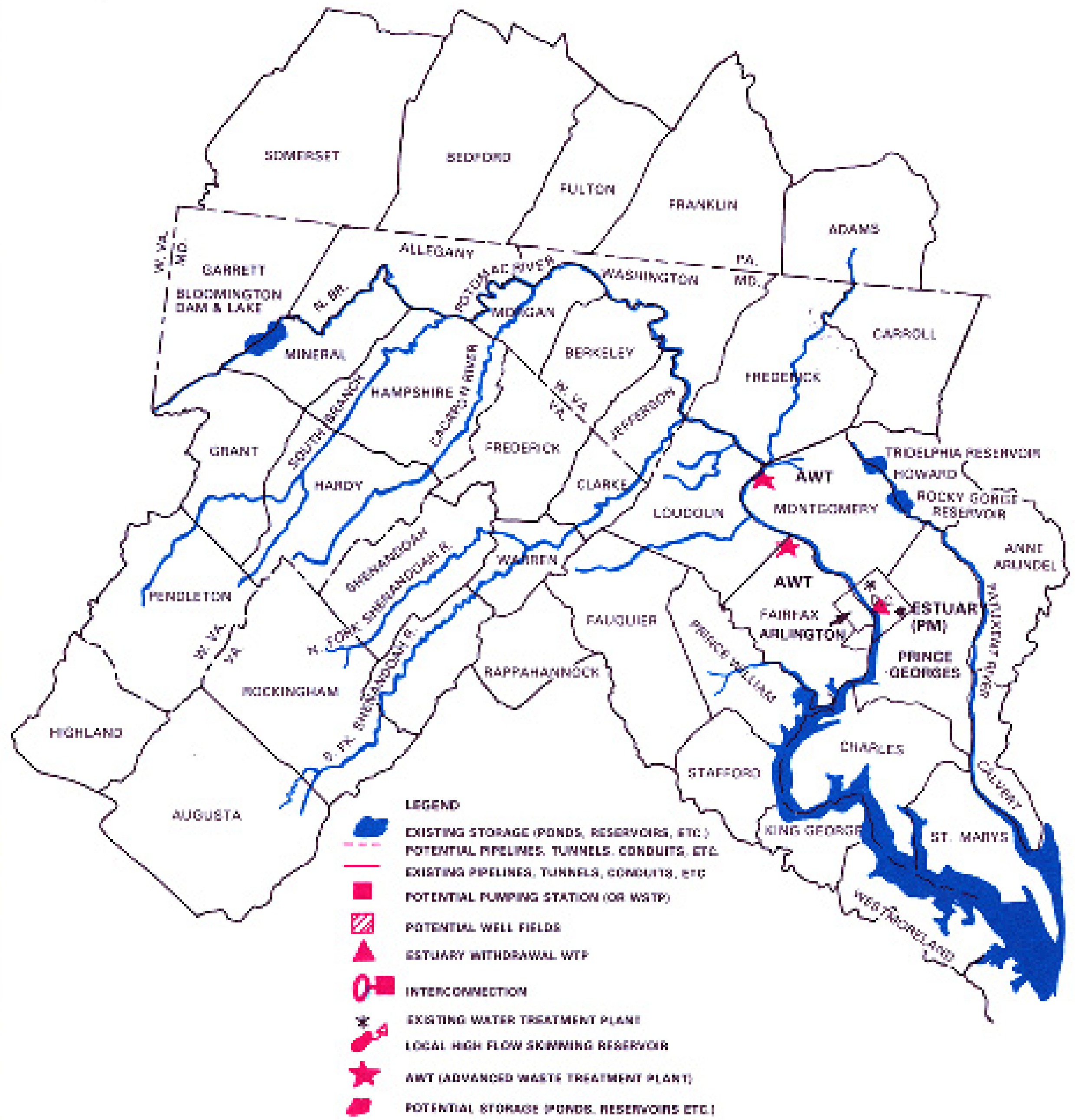
AWT 135 MGD (2000)

AWT 85 MGD; ESTUARY (PM) 100 MGD (2020)

YEAR	1970		1980		2000		2020	
	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY
ADDITIONAL DEMAND (MGD)	—	—	135	155	355	410	575	665
ADDITIONAL SUPPLY (MGD)	120	30	255	165	390	300	575	485
UNMET[1] DEMAND (MGD)	—	—	—	—	—	110	—	180

[1] TO BE MET THROUGH DEMAND RESTRICTIONS

BRANCH 2A



BRANCH TWO — A program relying exclusively on new or unproven technologies, undetermined ground water yields and emergency restrictions.

Branch 2 was formulated to minimize the kinds of adverse environmental impacts resulting from reservoir construction and based on acceptance of short term and long term seven day shortages in the WMA which might tend to reduce population growth. The branch would minimize the number of acres of land taken in potential reservoir areas and the degree of alteration of vegetation, aquatic and natural habitats in those areas. The effect on stream water quality would be uncertain and energy consumption would be high. Adverse environmental impacts from periodic water shortages might be experienced.

PROJECT DATA FOR BRANCH 2A

Project	Yield Month MGD	Yield 7 Day MGD	Capital Cost ($ Millions)	Annual OM&R ($ Millions)	Annual Cost ($ Millions)
Bloomington	135	135			
AWT	220	220	215.9	12.76	28.5
Estuary	100	100	93.5	0.96	7.8
Surplus	120	30	—	—	—
Total	575	485	309.4	13.72	36.3

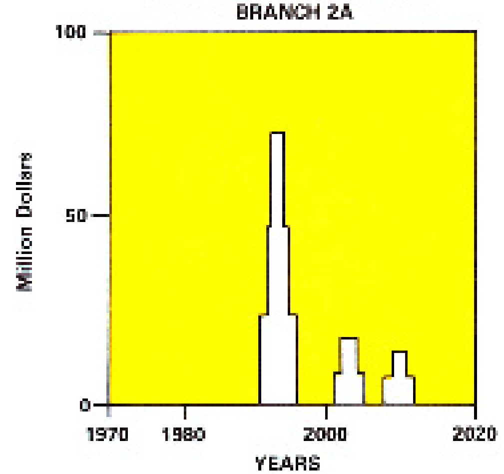
PROGRAM DESCRIPTIONS — 2A and 2B

1980 — With Bloomington operating by 1980, adequate supplies to meet monthly water supply demands will be available. Seven day deficits would exist and could be met through emergency restriction throughout the planning period.

2000 — Between 1980 and 2000 waste treatment plants would come on line in Fairfax and Montgomery Counties to treat 135 mgd of wastewater generated in the region to stream quality standards. Effluent from the plants would be discharged into the Potomac River 35 river miles upstream of Washington, D.C. Monthly deficits would be met by restrictions.

2020 — Between 2000 and 2020 a plant mix estuary treatment plant, supplying 100 mgd would be constructed in Program 2A. In program 2B 100 mgd would be obtained from wells in the Coastal Plain rather than from treated estuary water. Both branches would include AWT projects yielding an additional 85 mgd.

FIRST COST REQUIREMENTS
BRANCH 2A



PROGRAM RATIONALE

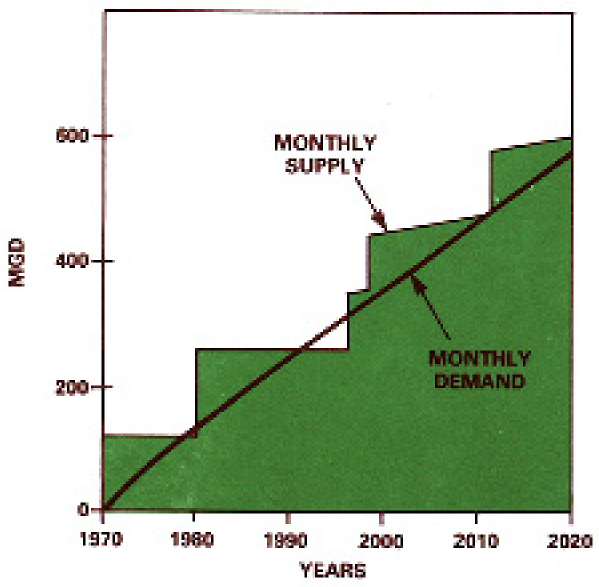
Branch 2A consists of emergency restrictions, AWT plants, and a plant mix estuary treatment plant. In this program, no projects specifically designed to meet the seven day peaking problem are included and recourse to emergency water use restrictions would be necessary. An important characteristic of the branch is acceptance of risk both in terms of repeated shortages and in the uncertainty incident to reliance on new or unproven technologies.

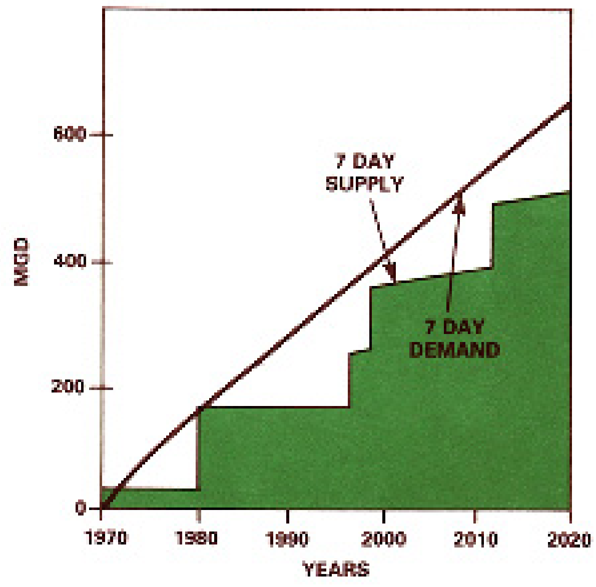
However, use of AWT plants for water supply has a number of advantages. They require little additional land, they can augment low flows and they cause minimal disruption of natural habitat, animals, vegetation and aquatic life. A major detriment, is the comparatively high energy requirements for plant processes and for pumping especially since the AWT plants would be operating year round. AWT plants are flexible and can be incremented as required by the amount of growth in a county.

A plant mix estuary treatment plant would have similar effects as the AWT plants. It requires less land but could have a potentially adverse effect on the environment of the upper estuary, when estuarine withdrawals are coupled with a low flow regime.

Program 2B is similar to Program 2A except the plant mix estuary treatment plant is replaced by coastal plain wells. The wells require a moderate amount of land, a moderate amount of energy and have a moderate impact on ecological systems, aquatic and terrestrial. Wells are fairly easy to increment as needed when growth requires. Recharge areas and areas immediately surrounding the wells need to be protected and require local land use ordinances to do so. Program 2A is primarily one of wastewater reuse, relying heavily on AWT plants and estuarine withdrawals. In both programs the technologies are relatively unproven except for wells. Before this program could be successfully launched the performance of these projects would have to be proven.

ADDITIONAL SUPPLY DEMAND VS. TIME
BRANCH 3 - AUGUST





PROJECT TIMING AND SUPPLY, DEMAND DATA - BRANCH 3

1980: BLOOMINGTON DAM AND LAKE 135 MGD

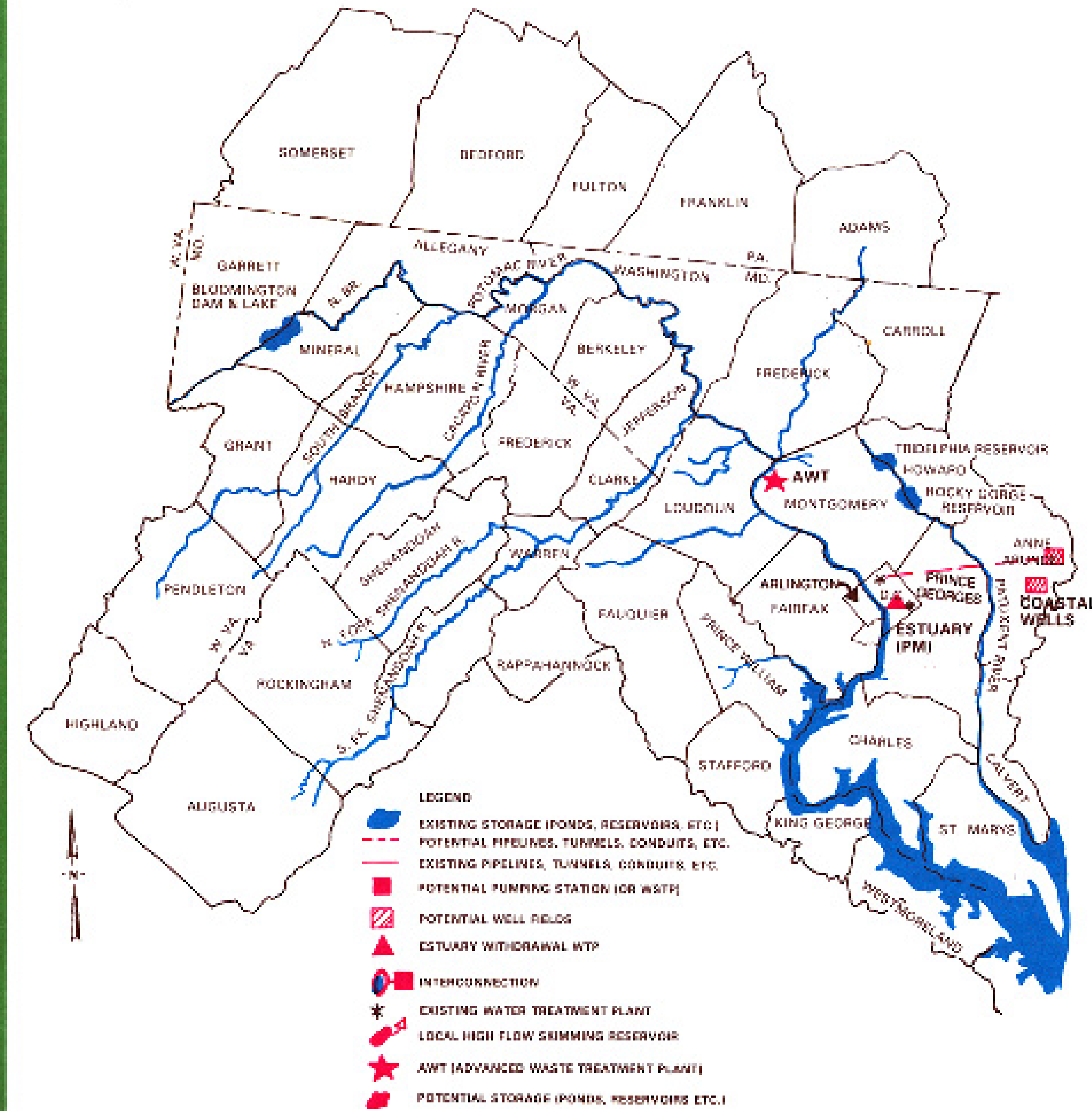
2000: AWT 90 MGD; EST. (PM) 100 MGD

2020: AWT 60 MGD; WELLS 100 MGD

YEAR	1970		1980		2000		2020	
	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY
ADDITIONAL DEMAND (MGD)	—	—	135	155	355	410	575	665
ADDITIONAL SUPPLY (MGD)	120	30	255	165	445	355	605	515
UNMET [1] DEMAND (MGD)	—	—	—	—	—	55	—	150

[1] TO BE MET THROUGH DEMAND RESTRICTIONS

BRANCH 3



BRANCH THREE — A program like Branch 2, based on use of new or unproven technologies, undetermined ground water yields and emergency restrictions. Branch 3 is, however, less costly to implement than Branch 2.

PROJECT DATA FOR BRANCH 3

Project	Yield Month MGD	Yield 7 Day MGD	Capital Cost ($ Millions)	Annual OM&R ($ Millions)	Annual Cost ($ Millions)
Bloomington	135	135			
AWT	150	150	100.4	6.08	13.4
Estuary	100	100	83.9	.91	7.0
Wells (C)	100	100	98.9	1.05	8.3
Surplus	120	30	—	—	—
Total	605	515	283.2	8.04	28.7

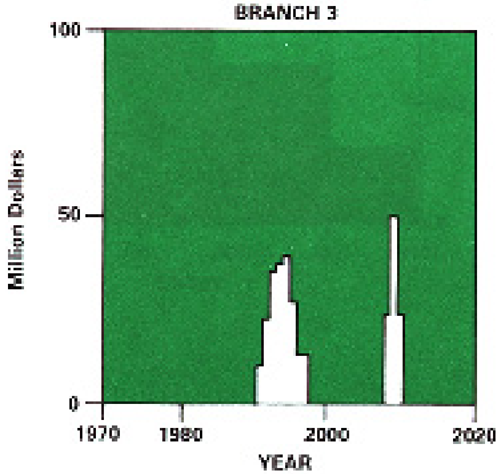
PROGRAM DESCRIPTION — 3

1980 — With Bloomington operating by about 1980, adequate supplies to meet monthly water supply demands will be available. Seven day deficits would exist throughout the planning period and could be met only through emergency restrictions.

2000 — Between 1980 and 2000, wastewater at the Montgomery County Advanced Waste Treatment Plant would be treated to stream quality standards and discharged into the Potomac upstream of the water supply intakes. Initial plant capacity would be 90 mgd. A plant mix estuary treatment plant, constructed in Washington, D.C., would supply 100 mgd. Monthly deficits could occur between about 1990 and 1995 and would also have to be met through restriction measures until the proposed AWT plants became operational.

2020 — Between 2000 and 2020 additional advanced waste treatment would provide 60 mgd and wells in the Coastal Plain would add 100 mgd to the WMA supply.

FIRST COST REQUIREMENTS
BRANCH 3

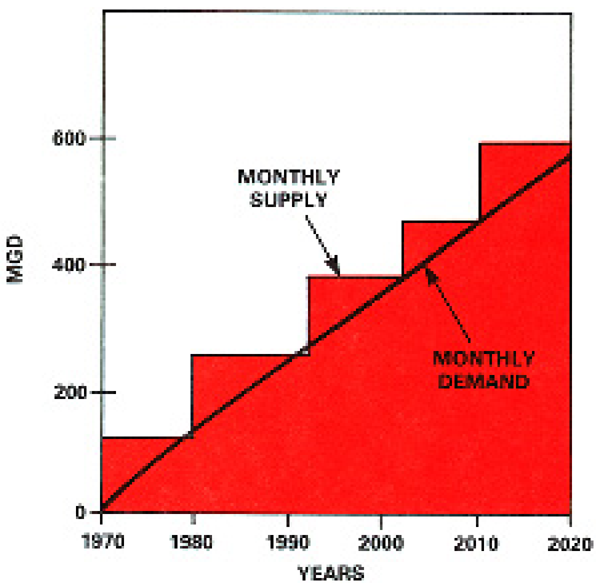


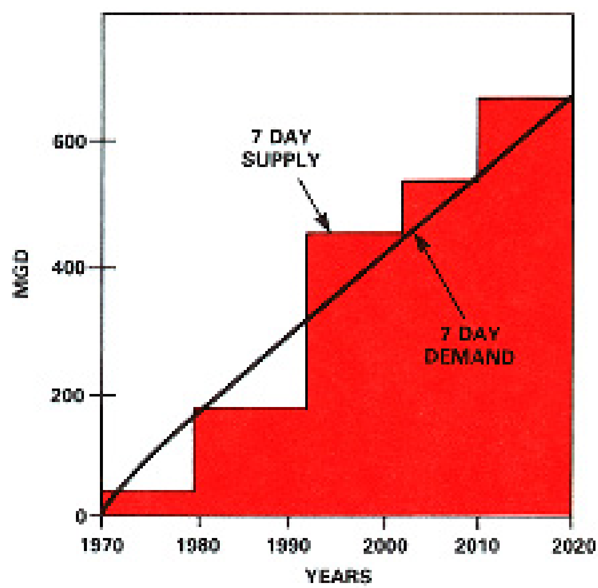
PROGRAM RATIONALE

Emergency restrictions, AWT plants, a plant mix estuary treatment plant and coastal plain ground water are the projects in Branch 3. In projects and objectives, this program is similar to Branch 2 but it is lower in cost. As in Branch 2, no facilities would be constructed specifically for meeting seven day peak demands and emergency water use restrictions varying as shown in the Supply-Demand graph would be required. Monthly restrictions of up to about 55 mgd would be needed for about five years. Restrictions, AWT plants, estuary treatment plants, and wells require only small to moderate amounts of land. However, operation of the projects during low flow periods might have adverse effects within the upper estuary and energy requirements for the AWT plants and estuary treatment plant are high. To reduce the cost, the estuary plant and coastal wells could be built to full capacity in one stage instead of in growth related increments.

The projects have moderate capital and operating costs for water supply with the exception of the estuary plant which has relatively high operating cost. The program also relies largely on local sources. This program brings into circulation and recirculation a large amount of water from the new technologies. It also demands commitment to a course of action that may not be completely successful because of the unproven technologies involved.

ADDITIONAL SUPPLY DEMAND VS. TIME
BRANCH 4B - AUGUST





PROJECT TIMING AND SUPPLY, DEMAND
DATA - BRANCH 4B

BLOOMINGTON DAM AND LAKE 135 MGD

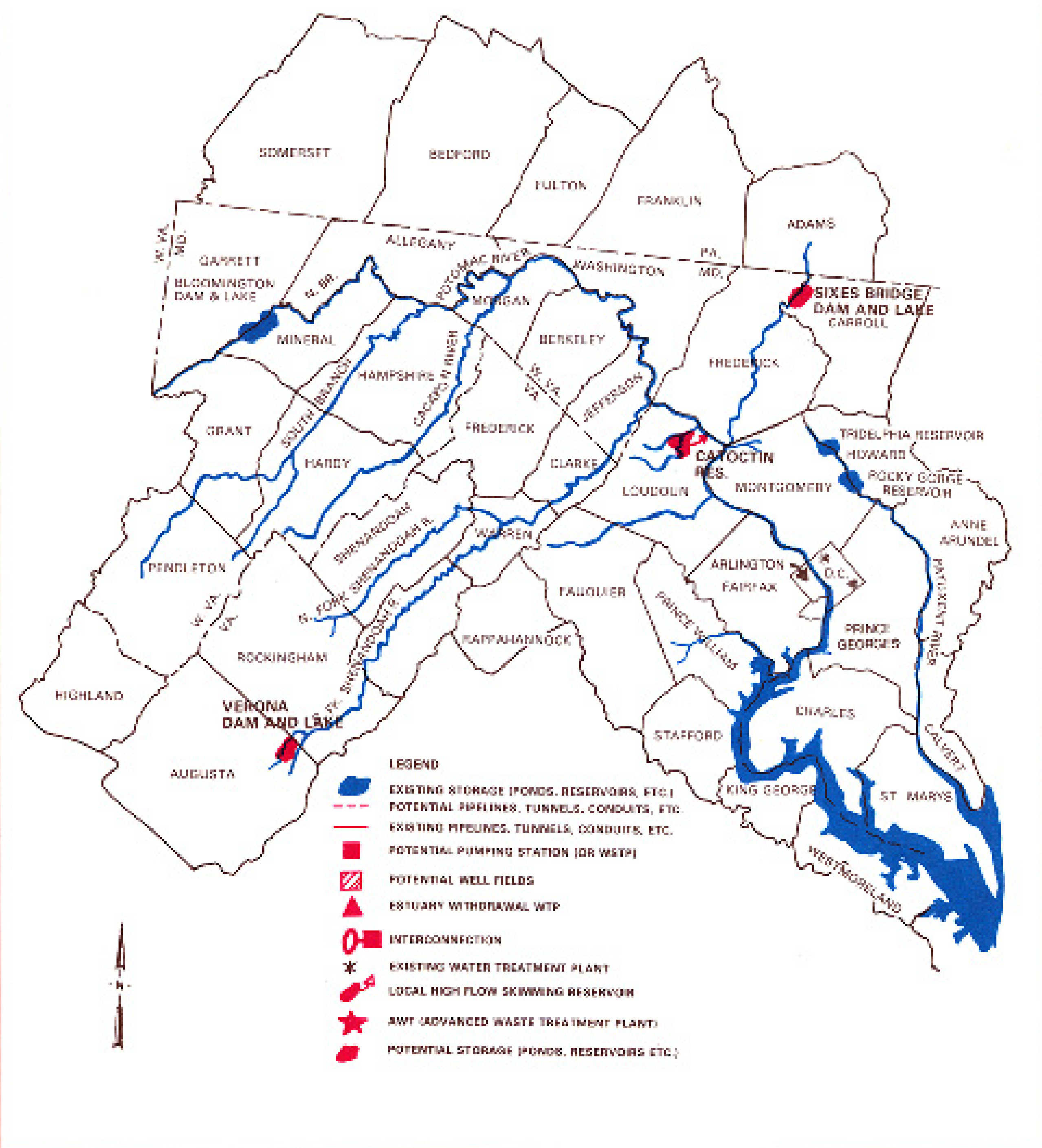
CATOCTIN RESERVOIR 130 MGD
CATOCTIN RES 7 DAY 155 MGD

SIXES BRIDGE 85 MGD

VERONA 130 MGD

YEAR	1970		1980		2000		2020	
	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY
ADDITIONAL DEMAND (MGD)	—	—	135	135	355	410	575	665
ADDITIONAL SUPPLY (MGD)	120	30	255	165	385	450	600	665

BRANCH 4B



BRANCH FOUR—A program based on surface water regulation by dam and reservoir projects. Emergency restrictions would be needed only in the early time periods before the major projects could be constructed.

Branch 4 represents maximum use of conventional, proven technologies with high reliability. It would require large land areas to be taken for the reservoir projects and the environmental impacts could be locally severe. Cost and energy requirements would be lower than for programs with high reliance on advanced treatment technologies. The program would also contain more certainty with respect to meeting public health standards than programs with high reliance on advanced treatment technologies.

PROGRAM DESCRIPTIONS—4A, 4B, 4C

1980 — With Bloomington operating by about 1980, adequate supplies to meet monthly water supply demands will be available.

2000 — Between the 1980 and 2000 time frames a high flow skimming dam and lake project on the Catoctin Creek in Loudoun County would supply 145 mgd in Program 4A. An interconnection between the Potomac and Patuxent Rivers through Montgomery County would be completed to supply up to 260 mgd to meet peak seven day demands in the branch through 2020. A Potomac high flow skimming dam and lake project on Catoctin Creek would supply 130 mgd to meet monthly demands and up to 285 mgd to meet peak seven day demands in Program 4B. In Program 4C a Potomac high flow skimming dam and lake project on Goose Creek would supply 480 mgd to meet monthly demands and 500 mgd for peak seven day periods. Emergency restrictions would be required to meet seven day demands early in the period before projects could come on line.

2020 — Between 2000 and 2020 in Programs 4A and 4B, Sixes Bridge Dam and Lake Project on the Monocacy River in Maryland would supply 85 mgd and Verona Dam and Lake Project on the Middle River in Virginia would supply 130 mgd. No projects would be needed for Program 4C during this period.

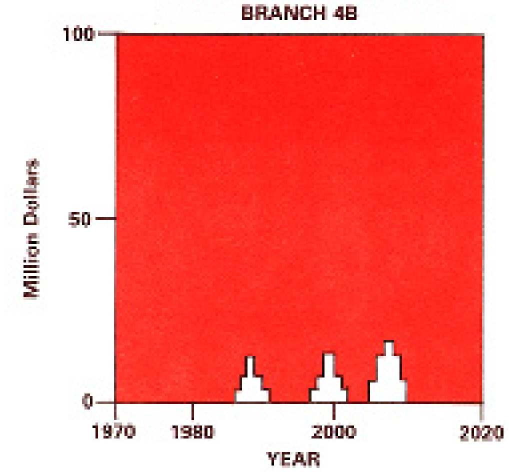
PROGRAM RATIONALE

This program was based primarily on water quantity and quality to be obtained through the use of conventional methods. It does not include wells or the new technologies. It would provide a highly reliable water supply in terms of low risk and quality of water supplied. The seven day peaking problem is approached in two different ways. In 4A, interconnections are used. In 4B and 4C, Catoctin and Goose Creek projects, respectively, designed to meet monthly demands would also meet seven day demands. Emergency restrictions would be used to meet interim seven day deficits such as those shown on the Supply Demand vs Time graph for Program 4B.

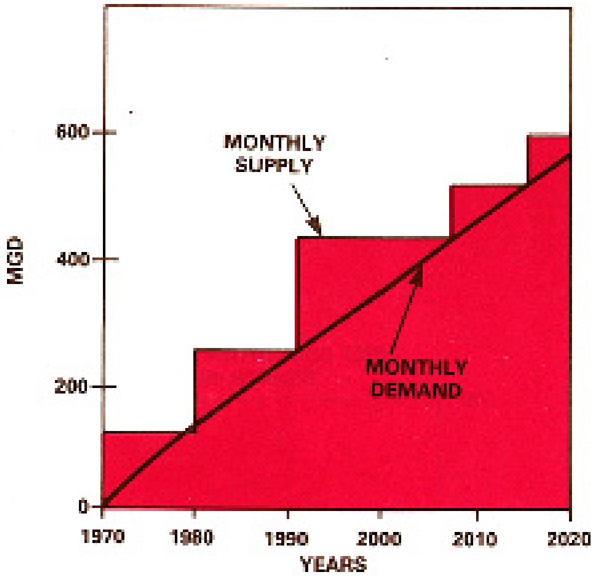
PROJECT DATA BRANCH 4B

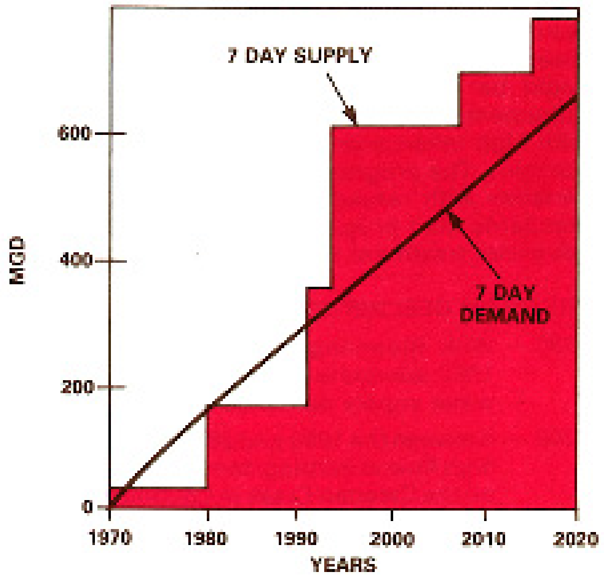
Project	Yield Month MGD	Yield 7 Day MGD	Capital Cost ($ Millions)	Annual OM&R ($ Millions)	Annual Cost ($ Millions)
Bloomington	135	135			
Catoctin	130	285	33.2	.21	2.6
Sixes Bridge	85	85	33.7	.03	2.3
Verona	130	130	55.3	.08	3.8
Surplus	120	30	—	—	—
Total	600	665	122.2	.32	8.7

FIRST COST REQUIREMENTS BRANCH 4B



ADDITIONAL SUPPLY DEMAND VS. TIME
BRANCH 5A - AUGUST



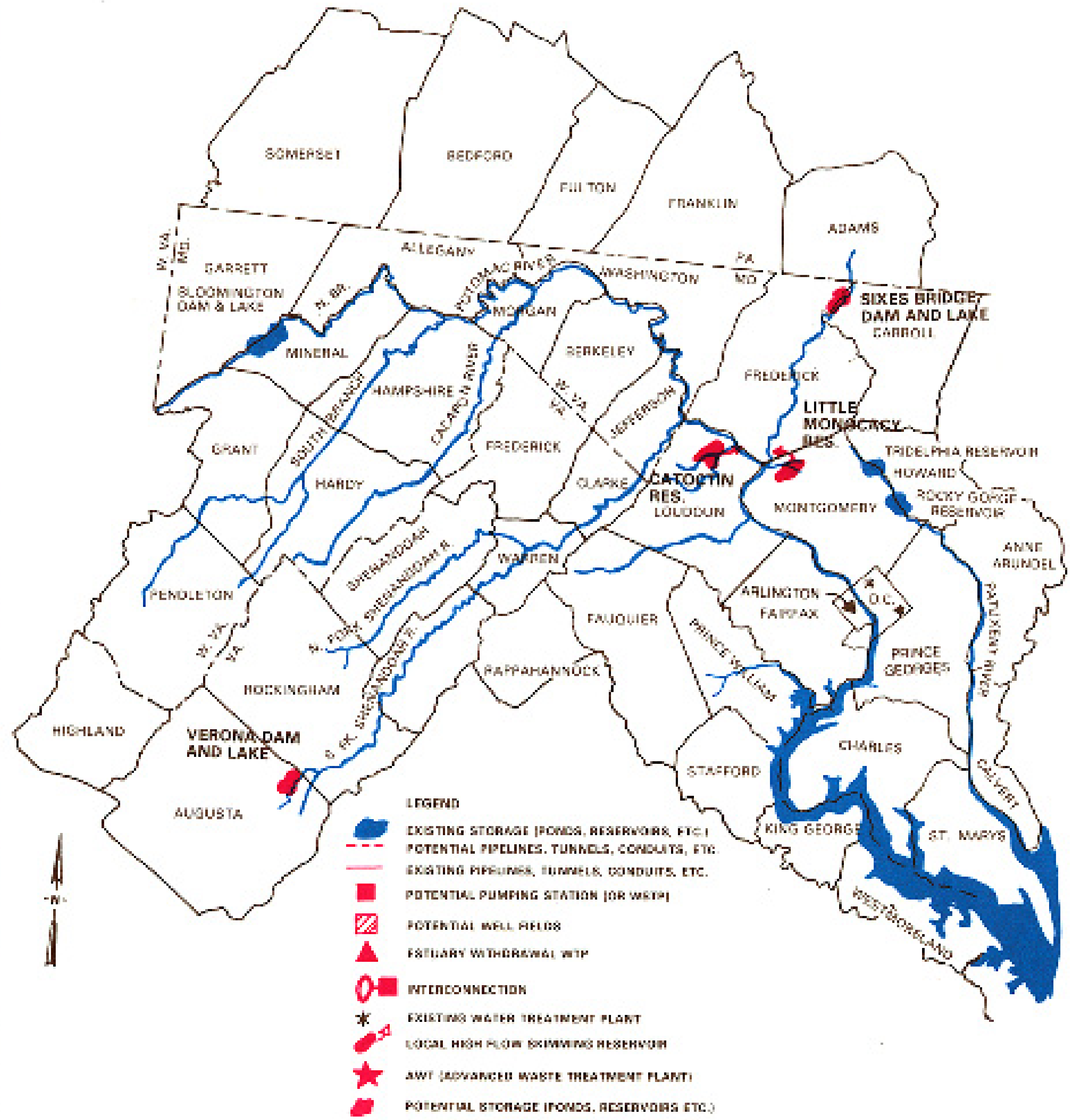


PROJECT TIMING AND SUPPLY DATA
BRANCH 5A

	1980	2000	2020
Projects	BLOOMINGTON DAM AND LAKE 135 MGD	LITTLE MONOCACY RESERVOIR 7-DAY 270 MGD; VERONA 190 MGD	SIXES BRIDGE 85 MGD; CATOCTIN RESERVOIR 85 MGD

YEAR	1970		1980		2000		2020	
	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY	MONTH	7 DAY
ADDITIONAL DEMAND (MGD)	—	—	135	155	355	410	575	665
ADDITIONAL SUPPLY (MGD)	120	30	255	165	445	625	615	795

BRANCH 5A



BRANCH FIVE—A program based upon the use of known and proven technologies.

Branch Five was formulated to utilize traditional measures for satisfying water supply needs. The assumptions are that a system is needed that best meets public health standards, imposes the least cost on the region, and provides a sufficient amount of water to support the projected growth and economy of the region. Energy requirements would be lower than for programs with high reliance on advanced treatment technologies.

PROGRAM DESCRIPTIONS—5A and 5B

1980 — With Bloomington operating by 1980, adequate supplies to meet monthly water supply demands are available. Seven day deficits would exist and could be met through emergency restriction.

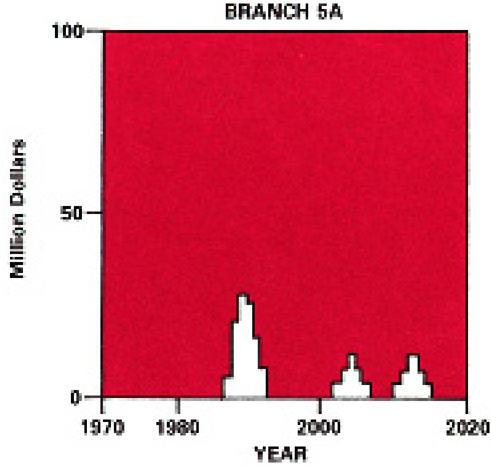
2000 — Between the 1980 and 2000 time frames seven day deficits will exist in both Programs and will be met by restrictions as needed, until projects come on line. In Program 5B Verona Dam and Lake Project would supply 190 mgd and Sixes Bridge 85 mgd. In Program 5A Verona Dam and Lake Project would supply 190 mgd and a Potomac high flow skimming dam and lake project on the Little Monocacy River in Montgomery County could supply up to 270 mgd to meet peak seven day demands.

2020 — Between 2000 and 2020 in Program 5A Sixes Bridge Dam and Lake Project would supply 85 mgd and a high flow skimming dam and lake project on the Catoctin Creek would supply 85 mgd. In Program 5B a high flow skimming dam and lake project on the Catoctin Creek in Loudoun County would supply 70 mgd to meet monthly demands and up to 260 mgd to meet critical seven day demands through 2020.

PROJECT DATA BRANCH 5A

Project	Yield Month MGD	Yield 7 Day MGD	Capital Cost ($ Millions)	Annual OM&R ($Millions)	Annual Cost ($ Millions)
Bloomington	135	135			
Little Monocacy	0	270	54.7	0.74	4.7
Verona	190	190	55.3	.07	3.8
Sixes Bridge	85	85	33.7	.03	2.3
Catoctin	85	85	33.1	.21	2.6
Surplus	120	30	—	—	—
Total	615	795	176.8	1.06	13.4

FIRST COST REQUIREMENTS BRANCH 5A



PROGRAM RATIONALE

This program is a river regulation system having high reliability and low cost. Program 5 is low risk and provides projects to meet the seven day peaking demand. Program 5A uses the Little Monocacy high flow skimming impoundment as a seven day peaking project which could be replaced by interconnections or emergency restrictions, if desired. Verona Dam and Lake and Sixes Bridge Dam and Lake with Potomac high flow skimming dam projects on Catoctin Creek and Little Monocacy Creek make up Program 5A. All projects provide a reliable source of water of high quality. In addition, both Verona and Sixes Bridge Dam and Lake could indirectly benefit downstream water quality through the increase of waste assimilation capacities during critical low flow periods which in turn could improve the instream habitat quality. Each of these projects would provide needed water surface area for forms of recreation not presently available in the area, such as fresh water boating, sailing and swimming. The little Monocacy and the Catoctin Creek local impoundments could benefit water quality in the mainstem Potomac River, but their operation as seven day reservoirs could detract from their recreational potential due to the rapid rate and magnitude of drawdown when needed. Also, these project sites possess environmental and social values that might not be compensated by replacement with water surface area. Consequently, these two projects are difficult to evaluate with respect to environmental quality.

All the projects have low capital and operating costs. They also provide ample water in order not to interfere with growth.

Program 5B consists of Verona and Sixes Bridges and a high flow skimming impoundment on the Catoctin Creek. The Catoctin Project would be used for both monthly and seven day peak demands. Both programs have high reliability and provide the flexibility to meet unforeseen growth demands since they rely on larger projects and both are relatively low in cost and have low energy requirements.

CHAPTER 7
THE NEW YORK METROPOLITAN AREA

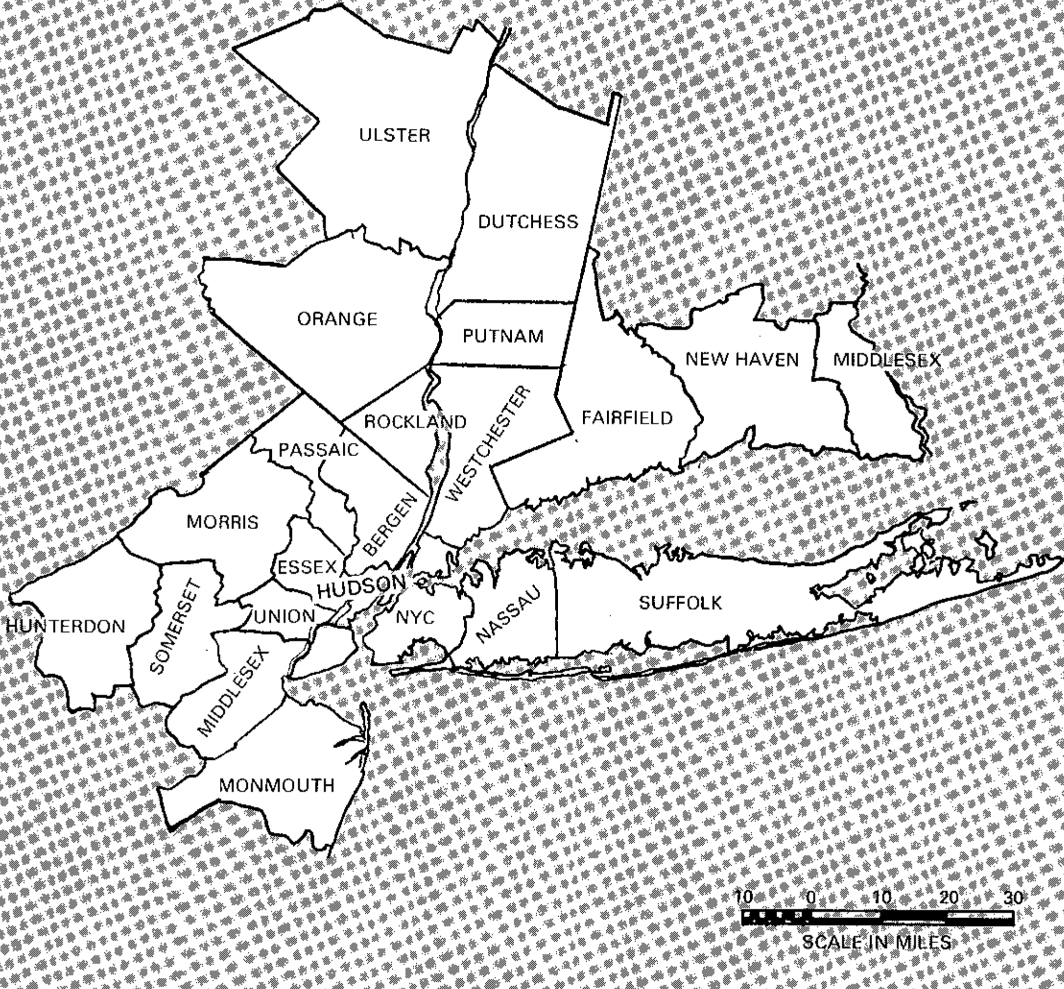


FIGURE 7-1. NEW YORK METROPOLITAN STUDY AREA.

CHAPTER 7: THE NEW YORK METROPOLITAN AREA (NYMA)

BACKGROUND

The New York Metropolitan Area (NYMA) consists of the New Jersey Counties of Passaic, Bergen, Hudson, Essex, Morris, Hunterdon, Somerset, Middlesex, Union and Monmouth, the Connecticut Counties of Fairfield, New Haven and Middlesex west of the Connecticut River and the New York Counties of Rockland, Orange, Ulster, Westchester, Putnam, Dutchess, Nassau and Suffolk, and New York City. The study of the NYMA has defined the regional water supply problems and has developed and evaluated potential solutions to them. Analysis and interpretation of data from a number of engineering, hydrologic, environmental, social, economic and institutional studies has provided the input on potential water supply projects and programs used as the basis for this chapter. These source studies are described in the attached Annotated List of NEWS Reports. As with the other two most critical areas, this information has been published and distributed widely to gather as much public and agency reaction as possible. Close coordination has been maintained with state and local agencies and various elements of state planning have been built into the planning process.

Following successive iterations of study, analysis, comment and revision, preliminary conclusions were reached about the most urgent water source development decisions to be made in order to assure the region of adequate water in the future. Alternative regional programs were presented in November 1975 in the NEWS Interim Report, *Critical Choices for Critical Years.* The report illustrated the nature of these decisions and the trade-offs that they would entail. A formulation stage public hearing was held in New York City on 19 March 1976, and on the basis of comments received at that meeting further technical studies were undertaken of a Hudson River Project which could meet the water supply deficit in the New York State portion of the metropolitan area. Details of the Hudson River Project are presented in the Appendix.

AREA PROFILE

The NYMA covers 9,345 square miles and includes 26 counties in three states (see Figure 7-1). It includes not only the City of New York, but other municipalities with populations exceeding 150,000 such as Newark and Jersey City in New Jersey, Yonkers in New York, and Bridgeport and New Haven in Connecticut. The area being studied also includes several hundred smaller communities.

The study area covers the densely populated area of the nation's most urbanized state, New Jersey. It contains the nation's largest city, New York, but also contains portions that are rural in nature.

It includes areas where industrial complexes are packed shoulder to shoulder, and areas where business and commerce are stacked in 100-story skyscrapers. It contains the nation's largest concentration of financial, trade, professional, business and communication services. Manufacturing, however, provides the major employment. Yet, the NYMA also includes areas where farming is a major business.

Population projections for the area have been made by many agencies. Although they were made at different times, extend over different periods, and do not cover exactly the same area, most agree that the area faces population increases by the year 2020. Presently developed water supplies are or will become inadequate to serve the needs of the area.

The population projections used in this report are based on the OBERS 1972 SERIES E projections, prepared by the Bureau of Economic Analysis of the U.S. Department of Commerce. Series E projections are based on long term nationwide attainment of "replacement level fertility" reflecting gradual reduction in annual rates of increase in population. The OBERS projections for each state have been broken down for areas within the NYMA proportional to the distributions used by each state for its own projections. The 1970 population and projections are shown in Table 7-1.

TABLE 7-1

NYMA POPULATION PROJECTIONS 1970-2020 (in millions)

	1970	1980	2000	2020
Northern New Jersey	5.1	5.8	6.9	7.9
New York City	7.9	8.0	8.4	8.8
Suburban New York State	4.3	4.9	6.5	7.7
Southwestern Connecticut	1.6	1.8	2.1	2.5
TOTAL	18.9	20.5	23.9	26.9

There have been other projections done for the area which are significantly lower. The principal differences involve the future of the New York State portion of the study area. The lowest projections for this portion are those of the State Economic Development Board, which are about 15% lower than the OBERS projections. However, when the Board projections were translated into water demand estimates by the State of New York, they produced a demand projection less than 2% below that developed by NEWS.

WATER DEMANDS

Total water use in 1970 in the NYMA exceeded 2.7 billion gallons per day. Per capita use varied widely in the study area. The non-industrial use ranged from 70 gallons per capita per day (gpcd) to over 200 gpcd and averaged 135 gpcd. Publicly supplied industrial use is even more variable, ranging from almost zero in some areas to 50 gpcd in the Central Naugatuck Valley of Connecticut. In New Jersey, publicly supplied industrial use accounted for 13% of the total water used from public systems. In New York, it represented 3% and in Connecticut 36%.

Projections of population, economic activity, residential density, domestic water use, and water conservation measures indicated that total water demand in the NYMA will exceed 5.1 billion gallons per day by 2020 (see Table 7-2). Water conservation devices were assumed in 25% of all new homes reducing water use by 18% for flush toilets, 7% for showers and 1% for washers.

Future industrial demand is a significant element of total demand. It is assumed that all additional industrial water requirements in the future will be publicly supplied, so that industrial withdrawals from public systems will increase from 8% of all public supply in the region in 1970 to 17% in 2020. Furthermore, the level of future demand is partly determined by the rate at which industrial recirculation and water saving technological change are assumed to increase. A uniform rate over the area has not been assumed as part of the base case for two major reasons:

1. The study includes parts of three independent political subdivisions, New Jersey, New York and Connecticut.

2. Industrial activity, while important in the Connecticut and New York portions of the study area, is not the most important sector of their economies. As a result, these states may be much more likely to impose early action controls on water use in industry than a state whose economic base is primarily industrial, such as New Jersey, and northern New Jersey in particular.

Recirculation rates and use of the most efficient technology can, however, be influenced by public policy, with great effect. For instance, Table 7-2 assumes that improvements will reduce the amount of water used for a given level of industrial output in 2020 to approximately one-half of the 1970 amount. This degree of improvement is expected to follow from water quality limitations on industrial discharges in strict compliance with the provisions of the Water Pollution Control Act Amendments of 1972 (P.L. 92-500).

TABLE 7-2

WATER SUPPLY SUMMARY-NYMA
(millions of gallons per day) [1]

	1970	1980	2000	2020
NEW YORK				
Average Annual Water Demand	1860	2070	2470	2980
Potential Local Supplies [2]	1700	1860	1950	2030
Water Supply Deficits	160	210	520	950
NEW JERSEY				
Average Annual Water Demand	680	820	1200	1650
Potential Local Supplies [2]	640	780 [3]	880 [3]	900 [3]
Water Supply Deficits	40	40	320	750
CONNECTICUT				
Average Annual Water Demand	220	290	360	500
Potential Local Supplies [2]	220	250	260	260
Water Supply Deficits	0	40	100	240

[1] Rounded to the nearest 10 mgd.

[2] It is assumed that demands are initially met by development of local supplies until the maximum capability of those supplies is reached.

[3] Includes the Round Valley Reservoir outlet works which was completed in 1977 with a yield of 80 mgd.

AVAILABLE WATER

The following sources of water were considered during the early phases of the study:

(1) Susquehanna River Basin
(2) Delaware River Basin
(3) Raritan River Basin
(4) Passaic River Basin
(5) South Jersey Ground Water
(6) Hudson River Basin
(7) Housatonic River Basin
(8) Connecticut River Basin
(9) Long Island Ground Water
(10) Southwestern Connecticut Ground Water
(11) Emerging technologies — this included considerations of various potential solutions such as: Desalination, Dual Water Distribution System, Long Distance Shipment, Partial Domestic Water Recycling, Advanced Wastewater Treatment and Iceberg Harvesting.
(12) Great Lakes
(13) St. Lawrence River

These sources were narrowed down to a more manageable number for further study. Screening criteria used were consideration of yield, proximity to the user and cost. The following sources were chosen for further analysis based upon this initial screening.

Hudson River

The largest single water resource within the study area, with a drainage area of 13,366 square miles, the Hudson River has an average flow exceeding 12,000 mgd at Poughkeepsie, New York. From its source in the Adirondack Mountains in northern New York, it flows southerly 147 miles to Troy, New York, and then becomes tidal for 153 miles to its mouth in New York Harbor.

Delaware River

One of the largest rivers on the east coast, the Delaware River has a drainage area of 6,780 square miles and an average flow of 7,600 mgd at Trenton, New Jersey. This major river flows through the states of New York, New Jersey, Pennsylvania and Delaware.

Housatonic River

The Housatonic drains 4,555 square miles of the western part of Massachusetts and Connecticut and has an average flow of 1,600 mgd at Stevenson Dam. It is widely used for recreation, power production, and industrial water supply and waste disposal.

Connecticut River

The Connecticut River drainage area of 11,250 square miles includes much of Vermont and New Hampshire, the western part of Massachusetts, and Connecticut. With an average flow of 10,300 mgd at Thompsonville, Connecticut, the river has been developed extensively for hydroelectric power and industrial water use, but the main stem has not been used for public water supply.

Other Sources

Other major sources of water supply in the NYMA are the smaller Passaic and Raritan Rivers in New Jersey and the ground water aquifers of Long Island and southern New Jersey. Desalinization of brackish water or sea water was also considered but because of cost, energy requirements and environmental effects, it is not considered a viable source for further analysis at this time. Conservation measures and devices have also been addressed, and if implemented could reduce the water demand in many areas.

PROJECTS CONSIDERED

In the first iteration of plan formulation for the NYMA, about 100 water supply projects were defined and screened for technical feasibility on the basis of the following considerations:

(1) Hydrology,
(2) Water quality,
(3) Downstream water requirements,
(4) Potability and treatment required,
(5) Costs,
(6) Institutional viability,
(7) Public acceptability, and
(8) Environmental concerns.

Based on these criteria, the initial list of projects was reduced to the 44 technically feasible projects shown on Table 7-3. Project descriptions and results of the analysis are contained in the NEWS report, "Engineering Feasibility Report on Alternative Regional Water Supply Plans for Northern N.J., New York City, Western Connecticut Metropolitan Area", November 1971. As indicated in the table, many technically feasible projects were eliminated because of cost, environmental concerns or institutional constraints. Sixteen projects, indicated on the table as "acceptable", were carried into the next level of plan formulation.

During the plan formulation process, water conservation practices were recognized as being equivalent to new supply projects and the following four measures were defined: increased metering in New York City, leakage control, use of domestic conservation devices, and management of Long Island's ground water resource. Twenty projects were therefore considered viable potential elements in alternative regional programs. A brief description of each project follows.

• **Tocks Island Lake Project Exchange**—This project (D-2 in Table 7-3) would have used New Jersey's tentative allotment from the Tocks Island Lake project for Delaware River control. In

TABLE 7-3

TECHNICALLY FEASIBLE PROJECTS

POTENTIAL SOURCE		REMARKS
Susquehanna River		
S-1*	Flood Skimming, Sidney to Cannonsville	Small yield, poor water quality, and geographically undesirable.
S-2	Diversion to Sanford Reservoir at Oquaga Creek	Environmental concerns, institutionally and geographically undesirable.
S-3	Diversion to West Branch w/out Upstream Storage	Small yield and geographically undesirable.
Delaware River		
D-1	Beaverkill Flood-Skimming and Cannonsville Flashboards	Institutional and legal constraints, small yield. Institutional and legal constraints, small yield.
D-2	Tocks Island Lake Project Exchange	Acceptable project.
D-3	New Jersey Northern Streams	High cost, low yield, environmental concerns.
D-4	Hawk Mountain Reservoir	High cost, transportation impacts, and poor public acceptance.
D-5	Beaver Kill Reservoir with Diversion from Hudson River	Environmental impacts and poor public acceptance.
Raritan River		
R-1	Raritan, Spruce Run-Round Valley	Acceptable project.
R-2	Confluence Reservoir	Acceptable project.
R-3	Delaware River-Tocks Island Lake Frenchtown Diversion	Acceptable project.
R-4	Delaware River Diversion: Flood-Skimming to Round Valley	Conflicts with R-2.
R-5	Delaware River Flood Skimming to Round Valley	High cost and institutional concerns.
R-6	Delaware and Raritan Canal Improvements Six Mile Run Reservoir	Limitations in canal capacity and small yield.
R-7	Crab Island Dam	Water quality and environmental concerns.
R-8	South River Tidal Dam	Small yield and environmental concerns.
Passaic River Basin		
P-1	Two Bridges Reservoir	Acceptable project.
P-2	Delaware River Diversion Frenchtown-Two Bridges	Acceptable project.
P-3	Delaware River Diversion Frenchtown-Canoe Brook	
P-4	Delaware River Diversion Port Jervis-Pequannock	These projects are similar to P-2 in that they use Tocks Island Water. P-2 was carried forward as an example of P-3, P-4, and P-5.
P-5	Delaware River Diversion Flatbrookville-Wanaque	
P-6	Hudson River-Ramapo Diversion	Acceptable project.
South Jersey Ground Water		
SJ-1	Fort Dix-Lebanon Forest Area	Acceptable project.
SJ-2	Fort Dix-Lebanon Forest Area plus Wharton Tract	Environmental and institutional concerns.
Hudson River		
HU-1	Hudson River Basin Storage	Acceptable project.
HU-2	Hudson River Basin Storage plus Lake Ontario	Institutional and cost concerns.
HU-3	Hudson River Basin Storage plus Lake Champlain	Environmental and institutional concerns.

TABLE 7-3 (CON'T)

HU-4	Hudson River Basin Storage with Compensating Releases	Environmental and institutional concerns.
HU-5	Hudson River Diversion with Upstream Storage	Cost and institutional constraints.
HU-6	Hudson River Project	Acceptable project.
HU-7	Black River Diversion To West Canda Creek	Cost and environmental concerns.
HU-8	Raquette River Diversion to Hudson River Headwater	Institutional and environmental concerns.
HU-9	Deerfield River Diversion into Hudson via Hoosic River	Institutional and environmental concerns.
Housatonic River		
HO-1	Trap Falls Reservoir	Acceptable project.
HO-2	Existing power reservoirs (Lake Lillinonah and Candlewood Lake)	Acceptable project.
HO-3	Roxbury High	Environmental and institutional concerns.
HO-4	Konkapot and Robbins	Acceptable project.
HO-5	Housatonic Development with Diversion to Kensico Reservoir	Cost and environmental concerns.
Connecticut River		
C-1	Middletown Diversion	Acceptable project.
C-2	Middletown Diversion, Stage 1	Institutional constraints.
C-3	Middletown Diversion, Stage 2	Institutional constraints.
C-4	Middletown Diversion	Institutional constraints.
Long Island Groundwater		
LI-1	Long Island Groundwater One-Way to N.Y.C.	Acceptable project.
LI-2	Long Island Two-Way Exchange	Acceptable project.

*Project identification numbers used in the source document.

this plan, New Jersey's entire 300 mgd allocation of water from the Tocks Island Dam and Lake Project would be allowed to flow down river for flow regulation. The New York City system would be required to maintain 830 mgd rather than 1130 mgd at Montague, N.J. in low flow periods. The additional 300 mgd retained in upstream reservoirs would then be available to meet the needs of northern New Jersey. Water could be delivered to northern New Jersey by either a pipeline from Shaft 4 of the Delaware Aqueduct to northern New Jersey, or a tunnel from Kensico Reservoir to Great Notch, New Jersey.

• **Raritan River, Spruce Run-Round Valley**—The yield of the Raritan River has been increased by 80 mgd through full use of the existing Spruce Run and Round Valley Reservoirs, the Hamden pumping station and force main to Round Valley. An improved outlet from Round Valley Reservoir (R-1 in Table 7-3) has been built by New Jersey to make use of this additional supply. Withdrawals for treatment and transmission to areas of use can be accomplished downstream at either new or existing intake sites.

• **Confluence Reservoir**—This project (R-2 in Table 7-3) would include a one billion gallon reservoir at the confluence of the north and south branches of the Raritan River, a pumping station at the reservoir, and a force main to Round Valley. The drainage area above the proposed dam site totals 466 square miles. Of this, some 41 square miles are already regulated by Spruce Run Reservoir and an additional 106 square miles are tributary to the Hamden pumping station connected to Round Valley Reservoir. Development of the additional drainage area would increase the upper Raritan River system safe yield by approximately 50 mgd.

• **Delaware River Diversion, Frenchtown - Round Valley**— This project (R-3 in Table 7-3) would consist of facilities at Frenchtown to divert 300 mgd of Tocks Island Lake or equivalent in-basin compensating storage releases to New Jersey. The water could be released to the Raritan River or pumped to either Round Valley or the Passaic River Basin. However, the development of this project will depend upon negotiating the necessary institutional arrangements by the Delaware

River Basin Commission within the provisions of the Basin Compact.

• **Two Bridges Reservoir**—This would be a multiple purpose project (P-1 in Table 7-3) to include the construction of a reservoir, a "dry-reservoir" detention area, and channel improvement. Water supply could be developed from a 26 billion gallon reservoir to be located near the confluence of the Pompton and Passaic Rivers at Two Bridges, New Jersey. Part of the storage would be used for flood control and the balance for water supply purposes, with an estimated yield of 100 mgd, exclusive of potential ground water recharge. The reservoir would require dikes to exclude poor quality runoff from the upper Passaic River in favor of better quality water diverted by gravity from the Pompton River.

• **Delaware River Diversion, Frenchtown - Two Bridges** — Delaware River releases from Tocks Island Lake or equivalent in-basin compensating storage of 300 mgd would be diverted at Frenchtown for delivery to Two Bridges Reservoir by a series of pipelines and pumping stations. (P-2 in Table 7-3) Additional reservoirs along the conveyance route would be required and intermediate points in New Jersey could be supplied. However, the development of this project will require negotiating the necessary institutional arrangements by the DRBC within the provisions of the Basin Compact.

• **Hudson River-Ramapo Diversion** — Hudson River water would be diverted to the Ramapo River to supplement the Wanaque supplies of the North Jersey District Water Supply Commission and the Hackensack Water Company (P-6 in Table 7-3). Water might also be provided to Orange and Rockland Counties in New York. The project would include an intake and pumping station at West Park, New York (opposite Hyde Park), a 31-mile aqueduct to the headwaters of the Ramapo River at Harriman, a pumping station at Pompton Lakes, and a force main to Wanaque Reservoir. Yield would depend on availability of storage in new and existing reservoirs but up to 250 mgd might be obtained without additional storage for regulating Hudson River flows.

• **South Jersey Ground Water**—South of the fall line between Trenton and Raritan Bay, New Jersey, the topography is relatively flat, resting upon coastal deposits dipping southeast into the Atlantic Ocean. Wells tapping the Cohansey and Kirkwood sand aquifers in the coastal area produce large quantities of water with the most abundant supplies close to the ground surface. Natural recharge of the coastal aquifers averages 20 inches per year, or 1.0 mgd per square mile. While the water ultimately may be needed in southern New Jersey, present demands are small and the potential exists for water to be exported to the densely populated regions in northeastern New Jersey. This project (SJ-1 in Table 7-3) could yield up to 200 mgd.

• **Hudson River Basin Storage** — This project (HU-1 in Table 7-3) is based upon the provision of additional upstream storage in the Hudson River for regulation of river discharges to allow high rates of continuous diversion downstream. Water would be diverted and treated on the east bank in the vicinity of Hyde Park. A variation of this project would have the diversion on the west bank near West Park. In either case a tunnel would be provided to Kensico Reservoir, one of New York City's reservoirs in Westchester County. The pumping stations and treatment facilities could be built in stages as needed, but the intake and tunnel would be constructed to ultimate capacity. To provide the necessary storage, the existing Hinckley Reservoir could be enlarged and Schaghticoke Reservoir could be constructed. The existing Sacandaga Reservoir power pool could also be re-regulated to increase the project yield. These upstream developments could provide an increase in safe yield up to approximately 1500 mgd. Intermediate areas could be supplied enroute by diversions from new tunnels or from existing facilities in the City system. Northern New Jersey could be supplied using a 12-foot diameter tunnel from Kensico Reservoir.

• **Hudson River Project**—As initially conceived, the project (HU-6 in Table 7-3) consisted of a first stage in which water would be diverted from the river near the west bank at West Park during high-flow periods, treated and pumped through a west bank tunnel extending to a point in Rockland County and then proceeding under the Hudson River to Kensico Reservoir in Westchester County. A second stage, basically the same as the Basin Storage Project, could be added. The project would utilize interconnections with existing New York City system aqueducts and reservoirs, and would provide water to New Jersey by pipeline or by a connection to the tunnel in Rockland County. The project was estimated to have a yield of up to 400 mgd.

The first stage project is the one selected for detailed analysis in the NYMA and alternative configurations, including one based on an east bank diversion and tunnel, are described in the appendix of this report.

• **Trap Falls Reservoir** — This project (HO-1 in Table 7-3) would be a run of the river diversion of 40 mgd from the lower Housatonic River into the existing Trap Falls Water Supply Reservoir. The project would support the New Haven Water Company and Bridgeport Hydraulic Company systems, enabling them to transfer water from existing sources to adjacent systems in Western Connecticut.

• **Housatonic River Power Reservoirs** — The Housatonic River could provide 160 mgd by converting existing power generation storage to water supply (HO-2 in Table 7-3). The top 10 feet of storage in Candlewood Lake would be utilized by pumping from the river in high-flow periods, and the top 50 feet of storage in Lake Lillinonah would be used for water supply releases rather than for power generation as in the past.

• **Housatonic River with Robbins and Konkapot**—This would be the same as the preceding project with the addition of two upstream off-river reservoirs; Robbins No. 2 at Falls Village, Connecticut and Konkapot No. 2 near Housatonic, Massachusetts (HO-4 in Table 7-3). These two reservoirs would be filled by pumping from the main river. The total safe yield of the project with all components would be 480 mgd.

• **Connecticut River Middletown Diversion**—This project (C-1 in Table 7-3) is a run of the river diversion which would deliver 90 mgd through a pipeline from the Connecticut River at Middletown, Connecticut, to New Haven following treatment at Middletown. Upstream storage of 16 billion gallons would be required in addition to the considerable storage required to control salt water intrusion into the estuary.

• **Long Island Ground Water**—The project consists of a well field in Suffolk County with collector mains, storage reservoirs, pumping station, chlorination facilities and transmission mains into Nassau County (LI-1 in table 7-3). It is estimated that a yield of 100 mgd could be obtained and that it would be developed in stages to meet increasing demand. However, Suffolk County needs beyond the year 2000 will necessitate the phasing out of this project as a regional source.

• **Long Island Exchange** — This project (LI-2 in Table 7-3) proposes that during normal, non-drought years, Long Island would be partially supplied by the surplus of the New York City system. This would permit natural recharge of the Long Island aquifers, with minimal pumping during normal and wet years. During dry periods, 150 mgd of Long Island ground water would be furnished to New York City, and Nassau County, over and above the requirements of Suffolk County communities. However, Suffolk's needs after 2000 will have increased to the point where this project would have to be phased out as a regional source.

• **Metering** — The implementation of universal metering in New York City might lead to significantly reduced water use, but the yield is not certain. The Corps of Engineers' estimate is that about 50 mgd savings could result from universal metering of all service connections in the City. However, it is considered to be an essential element in efficient water management and as a tool in monitoring the effectiveness of restrictive measures during water emergencies of all types.

• **Leakage Control**—A program to reduce water lost by leakage would entail a systematic procedure to detect and control leaks as they develop in a water system. In the mid-1950's New York City had such a program and the reported results indicate that it was highly cost-effective. While leakage control is considered important in every water system, an estimate was made only for New York City where average savings in water use of 25 mgd could be expected from an effort comparable to that previously in effect.

• **Domestic Conservation Devices**—Design and enforcement of building or plumbing codes requiring the installation of water devices in all new construction and major reconstruction could save as much as 55 mgd by the year 2000 in the New York portion of the NYMA and 85 mgd by 2020.

• **Long Island Total Resource Management Program**—This project comprises a resource management program combining techniques such as water conservation devices and methods; recharge of treated wastewater to aquifers through wells, basins, and spray irrigation of farmlands; recirculation; and surface water augmentation with treated wastewater. These devices, under a carefully monitored and coordinated program, would meet the needs of Nassau and Suffolk Counties through wise use of internal resources or in combination with outside sources such as the various Hudson River projects listed in Table 7-3.

There are technological uncertainties that must be resolved before such a program could be implemented. The Corps of Engineers and the New York State Energy Research Development Authority engaged in a joint study to develop the master plan of a demonstration project that could provide useful information for determining the feasibility of integrating water supply, wastewater management, power generation and land use control. One aspect of this investigation analyzed the implications of a full-scale program and addressed the efficiencies and technologies related to land application of treated wastewaters via various irrigation systems, ultimately to perfect ground water recharge techniques. The construction of thousands of stormwater recharge basins throughout Long Island by Nassau and Suffolk Counties would constitute the beginning of such a Total Resource Management program.

PROJECT CONSTRAINTS

Many of the listed projects are either complementary, that is, they depend upon each other for their estimated yields; or they are substitutes which cannot both be developed since they would use the same sources, the same storage or the same transmission systems. Consequently, substitutes could not be included together in the same regional programs or in the same time frame of a regional program, while complementary projects must be.

For example, the Delaware River diversion projects would be located downstream of the Tocks Island Lake Project and utilize its releases. Diversions to either Round Valley Reservoir or to Two Bridges Reservoir would preclude other projects also dependent upon use of storage in those sites such as the Confluence Reservoir. The Tocks Island Lake Project Exchange would not be feasible with any of the Hudson River high-flow diversion projects since all would utilize the storage and aqueduct capacity of the New York City system to provide additional yield.

If the Tocks Island project is deauthorized as recommended by the Corps of Engineers, a previously discarded project for high-flow skimming of the Delaware River at Frenchtown would again become viable for New Jersey. To obtain a yield of 300 mgd would require a number of smaller augmenting reservoirs upstream.

WATER SUPPLY PROGRAMS

Interim Report - 1975—An initial set of programs, composed of projects selected from those described, was presented for examination and review as a "decision tree" in the NEWS *Interim Report,* January 1975. Certain considerations were important in the development of the programs presented at that time.

1. The Hudson River was recognized to be the predominant potential major regional source of supply for southeastern New York and likely for Northern New Jersey in the next century. It was also recognized that a very long lead time would be necessary for implementation of any Hudson River project of the scale required to meet future needs of the area.
2. Development of the Delaware River by construction of the Tocks Island Lake Project remained a potential major source even though a majority of the Delaware River Basin Commission had withdrawn support for the project and the Corps of Engineers was recommending deauthorization.
3. The probability existed that, even with some development of the Delaware River to meet near term New Jersey needs, it appeared that utilization of the Hudson River would eventually be sought by New Jersey despite rather complex institutional issues relevant to export of water from New York reaches of the river.
4. Development of alternative sources for northern New Jersey was not expected to eliminate the eventual need for additional supplies from the Delaware River.

Following publication of the Interim Report, a formal public meeting was held in New York City on 19 March 1976 to present the alternative programs and to obtain public views as a basis for establishing the direction of continued planning for the region.

Public Involvement—In addition to coordination with state and local governmental officials, the NEWS staff sought to obtain the views of a wider segment of the public throughout the study by workshops and information meetings. Most were held in the New York portion of the NYMA since that area expressed the most interest in the study.

This effort revealed a number of significant issues with important implications for the consideration of early action projects. Foremost among these was the general opinion that water conservation measures, including universal metering, should be implemented in New York City. Projects which did not include an emphasis on conservation measures and devices were not considered likely to be viewed favorably in areas outside the city. Initially, the investigation of conservation measures centered on the metering of New York City. Subsequently, the study of water conservation for the region was expanded to consider domestic conservation devices, industrial conservation, leakage control, educational programs, pricing policies, and a drought contingency plan. Estimates of water savings or "yield" for each were established as well as the nature of the actions which local or state governments could take to achieve these yields. (For details see the Appendix, Part II, Section E, "Water Conservation Measures for the NYMA"). Conservation measures were considered important to all subsequent formulation since their effectiveness would determine the size, cost and operation of any early action project for the NYMA. However, it was found that conservation measures, by themselves, could not eliminate the region's existing and projected deficits.

Redefining The Region's Needs — As a consequence of the recognized importance of proper resource management, more specific analysis was made of the parameters of water demand, particularly conservation measures. It was concluded that, although differences of opinion might exist about particular items, the total NEWS water demands and deficits were an accurate representation of the needs of the region. It was further concluded that water conservation measures, locally implemented, should be a required precondition to Federal construction of any project, and would include universal metering, leakage control programs, use of water-saving domestic plumbing fixtures, and preparation of drought contingency plans. The potential yield of metering in New York City was finally adopted to be 50 mgd, after re-analysis indicated that any greater yield would be highly uncertain.

Finally, it was determined that primary emphasis would be placed on meeting the needs of the year 2000 rather than 2020, while retaining the flexibility to adapt to those later needs if and when they arise. The year 2000 needs—that is, the drought-condition deficits to be made up by a new regional project after all allowances were made for conservation efforts including metering — were found to be about 390 mgd for New York, 320 mgd for New Jersey and 100 mgd for Connecticut.

Focus on New York State—Through several iterations of the planning process, the NEWS Study progressively narrowed its effort to focus on the most promising early-action project: the Hudson River Project, which would divert water from the river during high-flow periods, treat it near the diversion point and deliver it by deep tunnel to the region's major demand centers. The selection process, and the alternative regional programs developed in the initial formulation stages, were described in the 19 March 1976 public meeting in New York City. At this meeting, the State of New York and other local interests indicated the need for a detailed analysis of the Hudson River Project and requested the Corps of Engineers to complete such a study. It was also urged that the NEWS Study include New York City Tunnel No. 3 in the project plan as an element required for its successful operation. City Tunnel No. 3 is a system of conveyance tunnels designed by the City of New York's Board of Water Supply. At the same meeting the States of New Jersey and Connecticut both expressed an interest in the NEWS Investigations, but indicated that their own in-state water resources would be adequate to meet their water supply needs up to 2000. They therefore found no need for any of the early action NEWS alternatives for their states to be analyzed in more detail.

Throughout the earlier stages of the study, the concept of high-flow skimming from the Hudson River took several forms from flood-skimming of very high discharges down to diversions during relatively low-flow periods. Implicit in each, however, was the assumption that the project would operate in conjunction with the New York City system of reservoirs and conveyances. Since the Hudson River Project would operate only when river flows exceed a pre-determined level because of potential saline water intrusion, the project would have a "safe yield" only to the extent that it could increase the yield of the total system in which it would be integrated. The project would require conjunctive storage and delivery capacity because of its intermittent operation. On this basis, a series of project variations with different yields and potential treatment plant sizes was developed. Tunnel routes were generally described as east bank or west bank without discussion of shaft sites, geology or specific route locations. The meeting of 19 March 1976 mandated a more detailed investigation of these issues.

Connecticut State Plan—The Connecticut Plan of Conservation and Development contains policies and project proposals specifically pertaining to water supply. The Plan consists of numerous localized ground water and surface projects. The following constraints were used by the State to determine suitable projects:

1. No streams were considered for water supply which had sewage discharges within the watershed.
2. No major relocations were allowed.

By the year 2020, implementation of the State Plan will provide an additional 170 mgd to the water supply in the NYMA portion of Connecticut. Of this, approximately 44 mgd will come from ground water development and the remainder from surface projects. While there are over a dozen surface projects, four will supply the bulk of water. The diversion of the Shepaug River in Roxbury will supply 52 mgd, the Trumbull Dam on the Poquonock River will add 6.5 mgd, the expansion of facilities at Lake Whitney will further add 15 mgd and the NYMA portion of the State will receive 13 mgd from the West Aspetuck River.

This plan includes preservation of future reservoir sites, management of watersheds to protect water quality at those sites, continuing to prohibit direct waste discharges into streams tributary to public water supplies and continuing to disallow the building of water supply facilities which would be fed by wastewater receiving streams.

Potential New Jersey State Plan — The State of New Jersey is developing a plan to meet its future needs through intensive development of intrastate sources. The plan is expected to include:

	MGD	
	2000	**2020**
Round Valley Modification [1]	80	80
Two Bridges High Flow Skimming	80	80
Washington Valley Reservoir	7	7
Manasquan-Lower Reservoir	10	10
Manasquan-Upper Reservoir	25	25
Confluence Reservoir	50	50
Six Mile Run Reservoir	63	63
Raise Round Valley	27	27
Monsville Reservoir	25	25
Delaware River Diversion	33	300
Hudson River Diversion or	(33)	163
South Jersey Ground Water	(33)	(163)
TOTAL	400	830

[1] Completed in 1977.

THE REVISED NYMA DECISION TREE

Like its initial version, the revised decision tree (Figure 7-2) presents alternative courses of action to meet the future water supply needs of the region. The alternatives it defines are, however, more limited in scope. This is a result of subsequent information provided by public input and technical analysis. For example, one constraint is that each state's needs should be met without recourse to interstate transmission of water, if possible. This constraint emerged when the States of New Jersey and Connecticut indicated they believe they have adequate intrastate sources to meet their demands beyond the year 2000. NEWS projections for the Connecticut portions of the NYMA indicate a greater demand than that upon which the Connecticut State Plan is based. Should these demands materialize the Connecticut Plan would need to be modified either by utilization of intrastate or out-of-state sources not now contemplated or more intensive development of the sources defined in the plan.

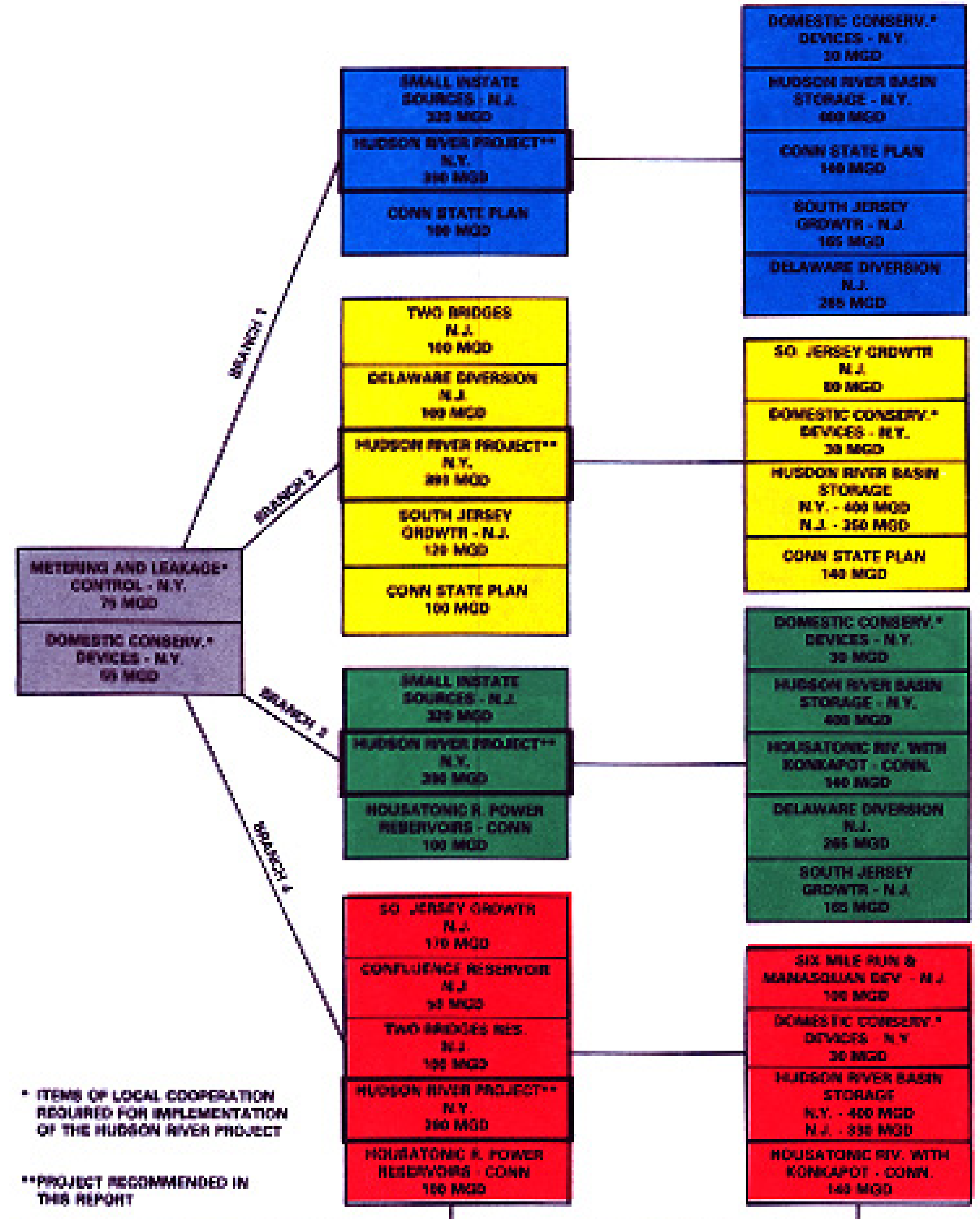
As the nature of the potential projects were revised, so was the timing of their development. The year 1980 is no longer a planning target, since the necessary decisions to meet the needs of that year should have already been made. The primary goal now is to assure an adequate water supply by the year 2000. Indeed, if major source development decisions are much further delayed, even that goal will be imperiled. The revised tree identifies the conceptual nature of the development needed, *e.g.,* additional in-basin storage in the Hudson River basin. Specific ways of doing this such as Hinckley Reservoir Expansion, Schaghticoke Reservoir or re-regulation of Sacandaga Reservoir, have been identified at the feasibility level, none of these appears to be clearly most desirable at this time.

All four branches of the revised decision tree share certain elements: metering and other conservation practices, the Hudson River Project, Hudson River Basin Storage and South Jersey Ground Water.

COSTS

Annual costs for locally-implemented projects are based on amortization over 35 years at 7.0% per year in New Jersey and Connecticut, and 8.5% in New York. For the federally funded Hudson River Project, a 50 year amortization period at 6⅜% has been used. The local interest rates were estimated on the basis of a statistical analysis, performed in the Spring of 1977, of the yields of long-term state and municipal government revenue bonds and utility bonds in each area. The Federal rate is that prescribed by the U.S. Water Resources Council.

FIGURE 7—2.
DECISION TREE—NYMA PROJECTS

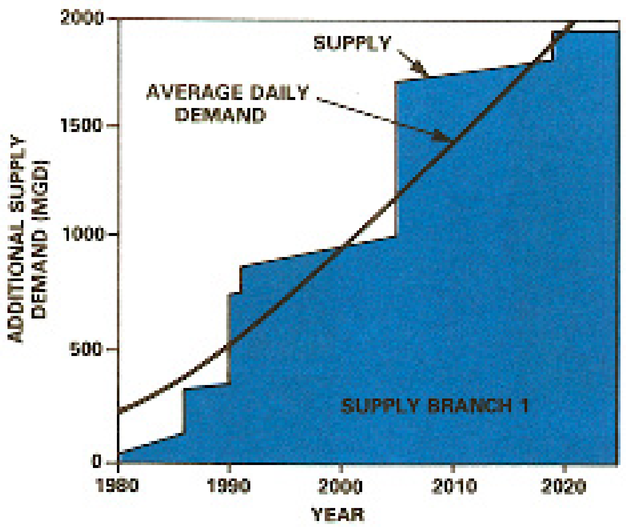


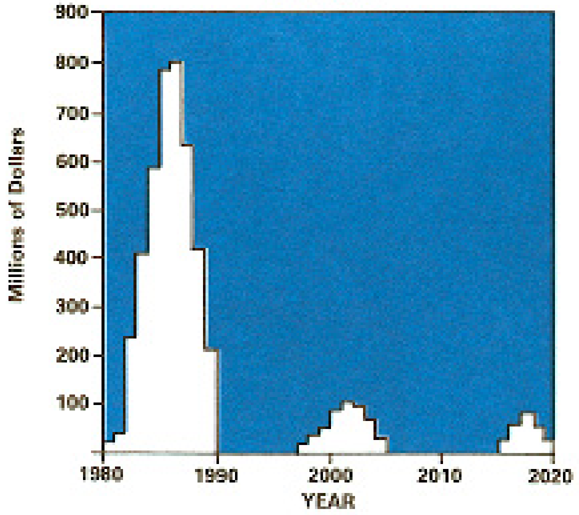
* ITEMS OF LOCAL COOPERATION REQUIRED FOR IMPLEMENTATION OF THE HUDSON RIVER PROJECT

**PROJECT RECOMMENDED IN THIS REPORT

BRANCH	THROUGH YEAR 2000			THROUGH YEAR 2020		
	DEFICIT (MGD)	YIELD (MGD)	TOTAL ANNUAL COST (MILLIONS '75$)	DEFICIT (MGD)	YIELD (MGD)	TOTAL ANNUAL COST (MILLIONS '75$)
I. NEW YORK	520	520	363	950	950	383
NEW JERSEY	320	320	35	750	750	103
CONNECTICUT	100	100	25	240	240	35
TOTAL	940	940	423	1,940	1,940	521
II. NEW YORK	520	520	363	950	950	282
NEW JERSEY	320	320	64	750	750	195
CONNECTICUT	100	100	25	240	240	35
TOTAL	940	940	452	1,940	1,940	512
III. NEW YORK	520	520	363	950	950	383
NEW JERSEY	320	320	35	750	750	103
CONNECTICUT	100	100	16	240	240	26
TOTAL	940	940	414	1,940	1,940	512
IV. NEW YORK	520	520	363	950	950	286
NEW JERSEY	320	320	58	750	750	183
CONNECTICUT	100	100	16	240	240	26
TOTAL	940	940	437	1,940	1,940	495

ADDITIONAL SUPPLY, DEMAND VS. TIME BRANCH 1





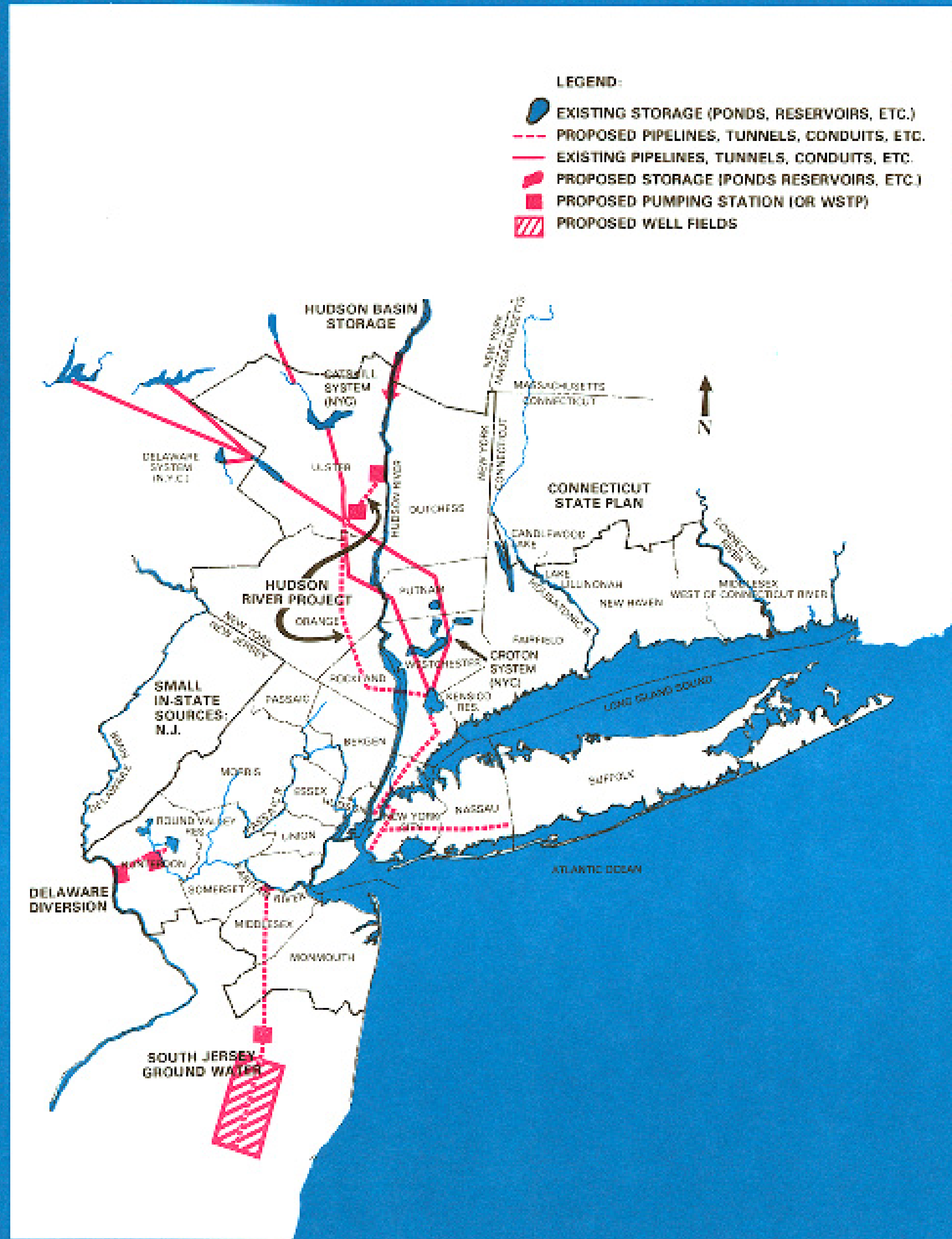
DECISION TREE - BRANCH 1

* ITEMS OF LOCAL COOPERATION REQUIRED FOR IMPLEMENTATION OF THE HUDSON RIVER PROJECT

**PROJECT RECOMMENDED IN THIS REPORT

YEAR	2000	2020
DEFICIT (MGD)	940	1,940
YIELD (MGD)	940	1,940

BRANCH 1



BRANCH NUMBER ONE

Program Description

2000 - The small in-state projects for New Jersey, comprising projects such as Confluence and Six Mile Run Reservoirs, Manasquan River development, a small Delaware River diversion and interbasin transmission features, has been indicated by the State as adequate to meet New Jersey's 320 mgd deficit. The Hudson River Project would provide New York with 390 mgd, and the Connecticut State Plan would supply that state with 100 mgd. In addition, the implementation of water conservation policies, including Metering (50 mgd) Leakage Control (25 mgd) and Domestic Conservation Devices (55 mgd), will save the equivalent of 130 mgd in New York.

2020 - New Jersey would require an additional 430 mgd to meet its 2020 deficit. New Jersey has available to meet this need the following developments: an increase of the Delaware Diversion from 35 mgd to 300 mgd, supported by equivalent in-basin storage, and the development of South Jersey Ground Water for about 165 mgd. For New York, the Hudson River Basin Storage Project would have to be developed to provide 400 mgd. This storage could be achieved either through re-regulation of existing reservoirs or new reservoir development. It is recognized that new reservoir development is not currently a viable alternative. It is not being proposed as a solution now, but as a long run alternative which must be reconsidered in the future as the need for additional water arises. Domestic conservation devices would provide the additional 30 mgd needed to meet New York's deficit. Yield from the Connecticut State Plan would need to be increased from 170 mgd to 240 mgd by more extensive development of sources included in the plan or by including sources not considered in the plan.

PROGRAM RATIONALE

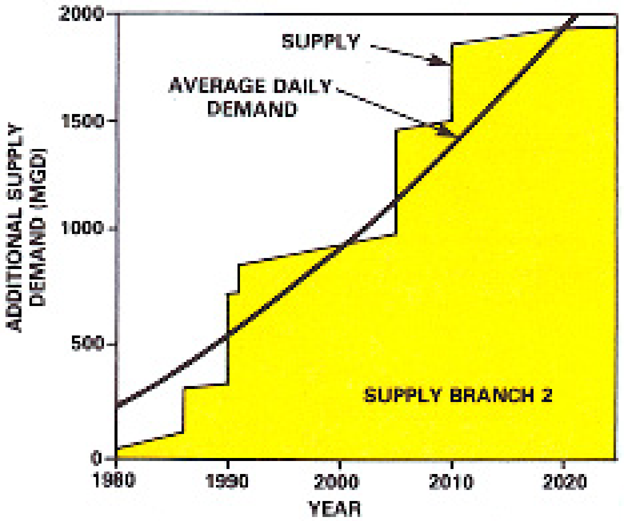
This branch, utilizing the Connecticut State Plan and the small in-state projects identified by New Jersey, would require the least institutional rearrangement and could therefore be the most easily implemented course of action.

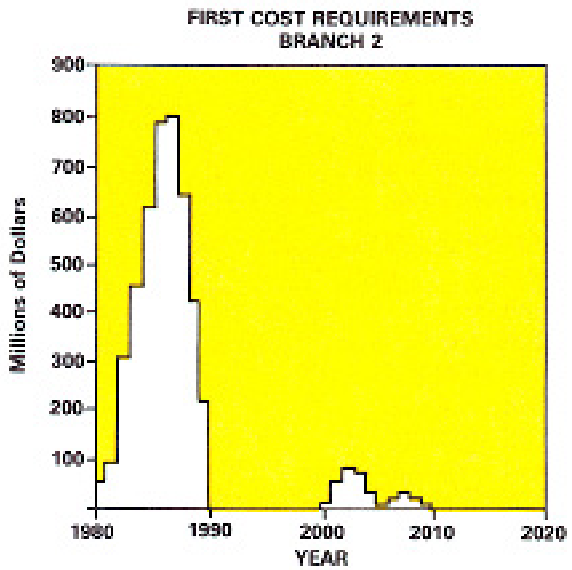
PROJECT DATA FOR BRANCH 1

PROJECT	SAFE YIELD (mgd)	FIRST COST (mill. 1975 $)	ANNUAL COST (mill. 1975 $)	COST PER MG (1975 $)
Small In-State Sources in N.J.	320(1)	252	35	300
South Jersey Ground Water	165	256	26	434
Delaware Div.	265	342	42	434
Metering in NYC	50	154	16	858
Leakage Control in NYC	25	—	1	148
Domestic Cons. Devices (NY)	85	—	—	—
Hudson River Project (2)	390	3,696	346	2,431
Hudson River Basin Storage	400	133	20	137
Connecticut State Plan	240	136	35	400

(1) Includes initial Delaware diversion of 35 mgd.
(2) Annual cost for Hudson River Project assumes amortization at 6.375% per year over 50 years.

ADDITIONAL SUPPLY, DEMAND VS. TIME
BRANCH 2





DECISION TREE - BRANCH 2

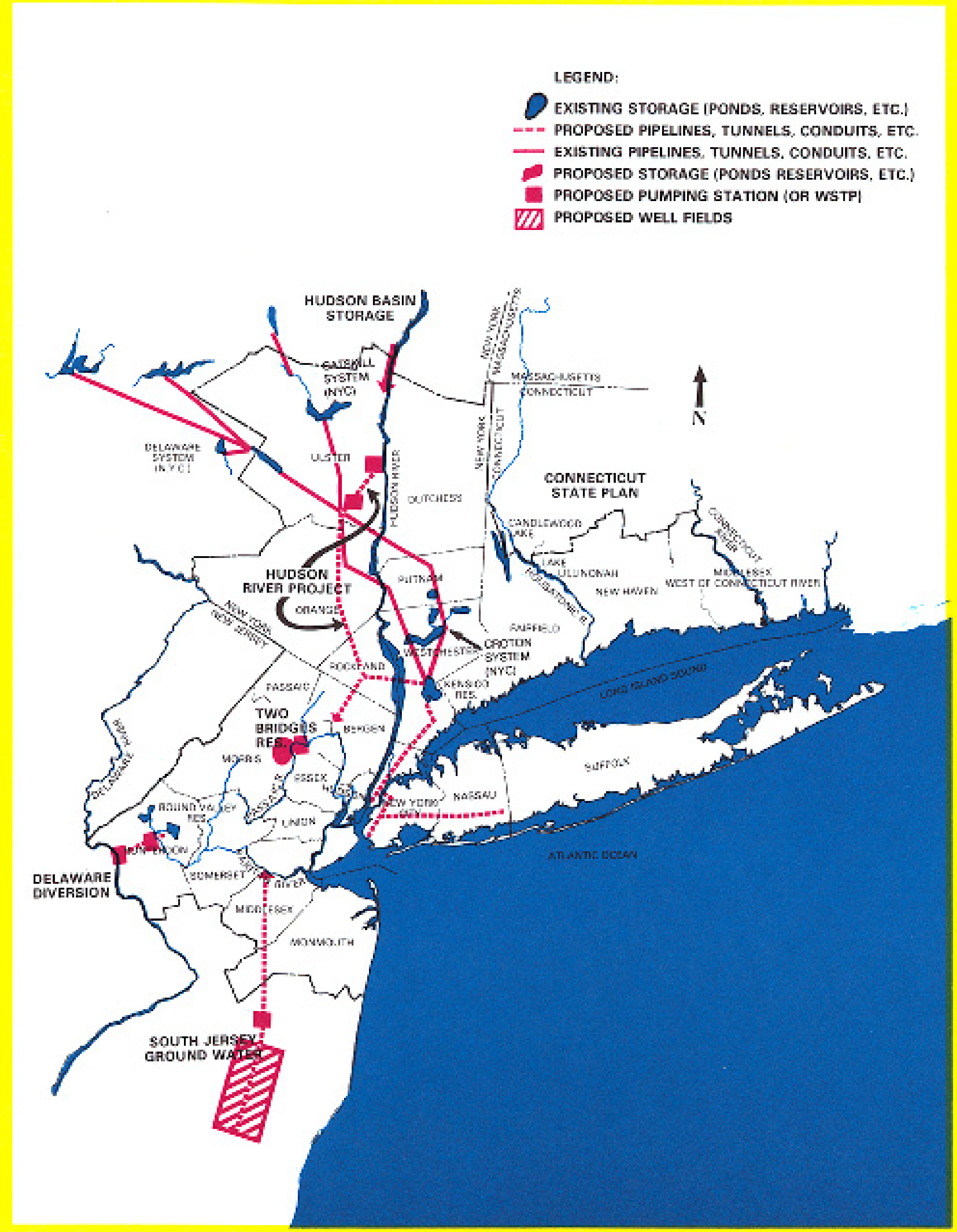
METERING AND LEAKAGE* CONTROL - N.Y. 75 MGD	TWO BRIDGES N.J. 100 MGD	SO. JERSEY GRDWTR N.J. 80 MGD
DOMESTIC CONSERV.* DEVICES - N.Y. 55 MGD	DELAWARE DIVERSION N.J. 100 MGD	DOMESTIC CONSERV.* DEVICES - N.Y. 30 MGD
	HUDSON RIVER PROJECT** N.Y. 390 MGD	HUDSON RIVER BASIN STORAGE N.Y. - 400 MGD N.J. - 350 MGD
	SOUTH JERSEY GRDWTR - N.J. 120 MGD	CONN STATE PLAN 140 MGD
	CONN STATE PLAN 100 MGD	

* ITEMS OF LOCAL COOPERATION REQUIRED FOR IMPLEMENTATION OF THE HUDSON RIVER PROJECT

**PROJECT RECOMMENDED IN THIS REPORT

YEAR	2000	2020
DEFICIT (MGD)	940	1,940
YIELD (MGD)	940	1,940

BRANCH 2



BRANCH NUMBER TWO

Program Description

2000 - New Jersey's needs would be met by the development of larger in-state sources including 100 mgd each from Two Bridges Reservoir and the Delaware Diversion, and 120 mgd from South Jersey Ground Water. The Hudson River Project would provide New York with 390 mgd, and the Connecticut State Plan would supply 100 mgd. Conservation measures including Metering (50 mgd), Leakage Control (25 mgd) and Domestic Conservation Devices (55 mgd) would provide an equivalent of 130 mgd in New York.

2020 - New Jersey would require an additional 430 mgd to meet its 2020 deficit, which would mean expansion of the South Jersey Ground Water Project to its estimated capacity of 200 mgd, and utilization of 350 mgd from the Hudson River Basin Storage project. For New York, the Hudson River Basin Storage Project would provide 400 mgd. This will require increases in basin storage by either reregulation of existing reservoirs or new reservoir construction. Domestic Conservation Devices will provide an additional 30 mgd. The Connecticut State Plan would need to be expanded from 100 mgd to 240 mgd by more extensive development of the sources included in the plan or including sources not considered in the plan.

PROGRAM RATIONALE

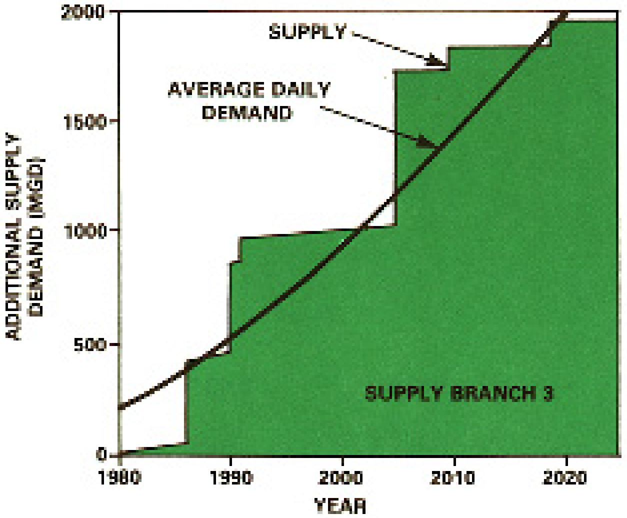
This branch displays an alternative near-term plan for New Jersey, utilizing fewer and larger projects, of a more regional nature. It also comprises a larger Federal role, with interstate utilization of the Hudson.

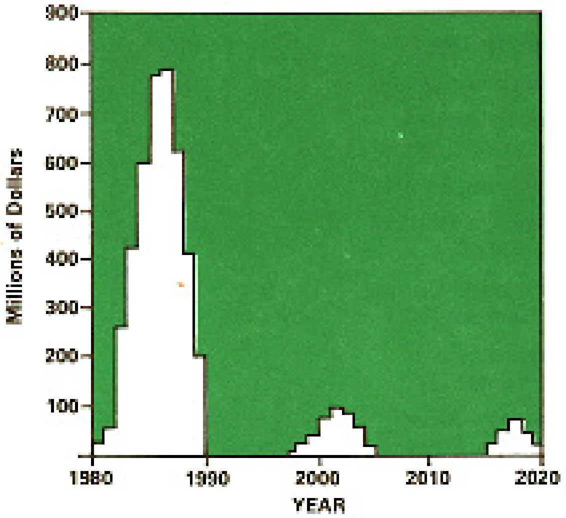
PROJECT DATA FOR BRANCH 2

PROJECT	SAFE YIELD (mgd)	FIRST COST (mill. 1975 $)	ANNUAL COST (mill. 1975 $)	COST PER MG (1975 $)
Two Bridges	100	130	18	493
Delaware Div.	100	182	27	730
South Jersey Ground Water	200	310	32	434
Metering in NYC	50	154	16	858
Leakage Control in NYC	25	—	1	148
Domestic Cons. Devices (NY)	85	—	—	—
Hudson River Project (1)	390	3,696	346	2,431
Hudson River Basin Storage	750	247	37	135
Connecticut State Plan	240	136	35	400

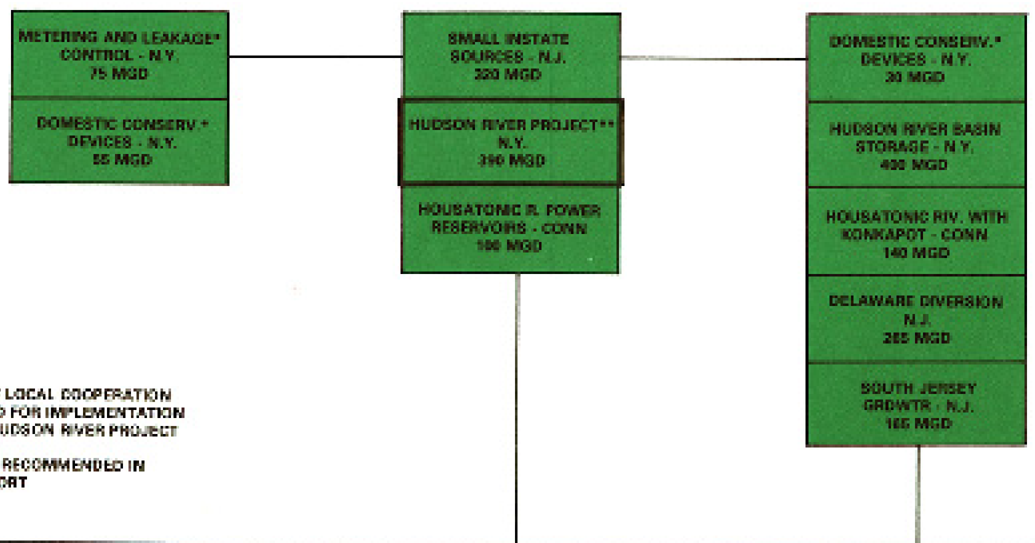
(1) Annual cost for Hudson River Project assumes amortization at 6.375% per year over 50 years.

ADDITIONAL SUPPLY, DEMAND VS. TIME
BRANCH 3





DECISION TREE — BRANCH 3

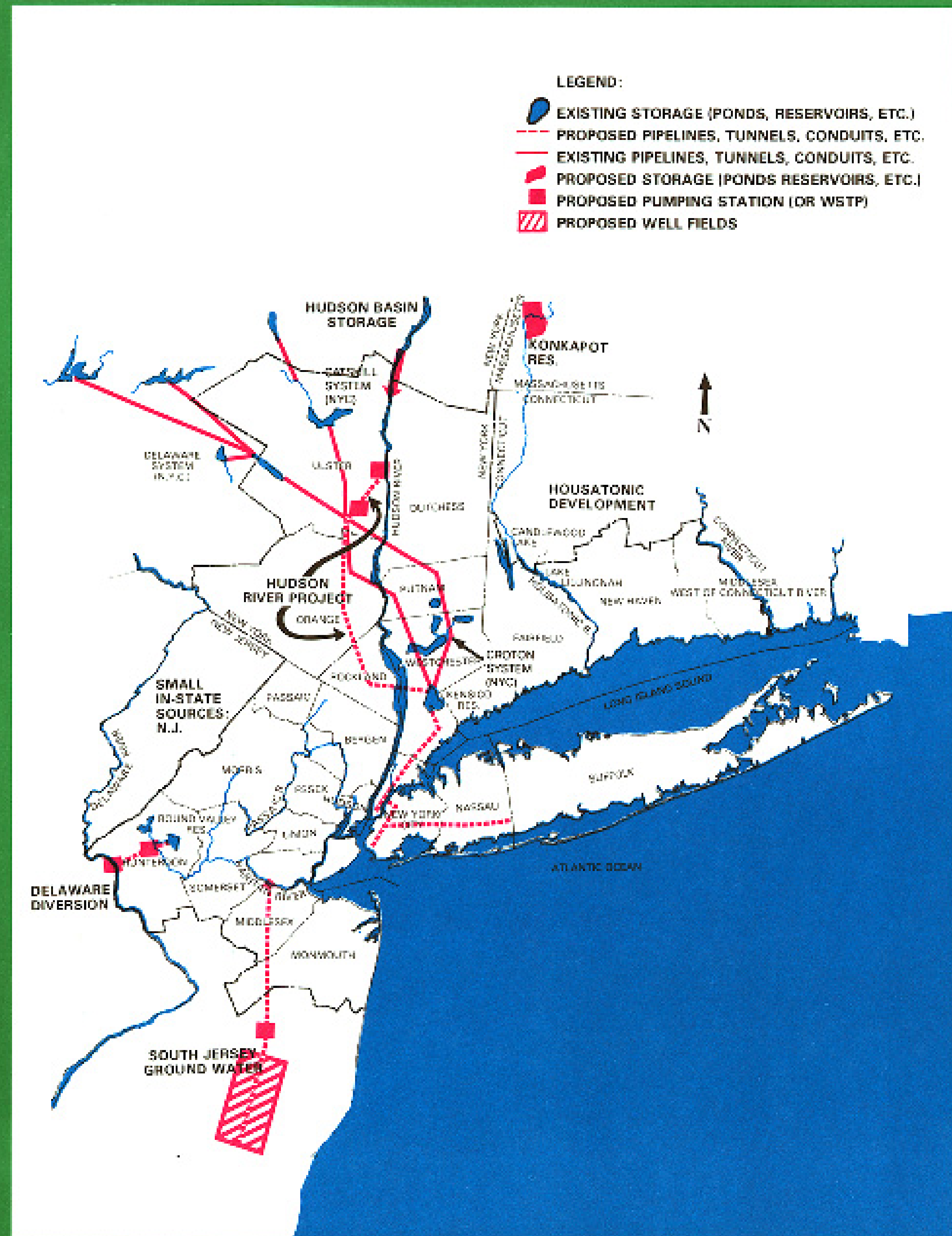


* ITEMS OF LOCAL COOPERATION REQUIRED FOR IMPLEMENTATION OF THE HUDSON RIVER PROJECT

**PROJECT RECOMMENDED IN THIS REPORT

YEAR	2000	2020
DEFICIT (MGD)	940	1,940
YIELD (MGD)	940	1,940

BRANCH 3



BRANCH NUMBER THREE

Program Description

2000 - The small in-state projects for New Jersey, comprising such projects as Confluence and Six Mile Run Reservoirs, Manasquan River development a small Delaware River diversion and interbasin transmission features, has been indicated by the state as adequate to meet New Jersey's 320 mgd deficit. The Hudson River project would provide New York with 390 mgd, and re-regulation of Housatonic River power reservoirs would increase safe yields in Connecticut by the 100 mgd necessary to meet the deficit. Conservation practices, including Metering (50 mgd), Leakage Control (25 mgd) and Domestic Conservation Devices (55 mgd) would yield an additional 130 mgd for New York.

2020 - New Jersey would require an additional 430 mgd to meet its 2020 deficit. The State has indicated South Jersey Ground Water could be developed to provide about 165 mgd. This still leaves a deficit of 265 mgd, which could be met by increasing its Delaware Diversion from 35 mgd to 300 mgd, supported by equivalent in-basin storage. For New York, the Hudson River Basin Storage Project would be needed to provide 400 mgd by either construction of new upstream reservoirs or re-regulation of existing reservoirs. Domestic Conservation Devices would yield an additional 30 mgd. Safe yields in Connecticut could be increased by an additional 140 mgd by the further development of the Housatonic River, including additional re-regulation of the Housatonic power reservoirs and construction of Konkapot Reservoir.

PROGRAM RATIONALE

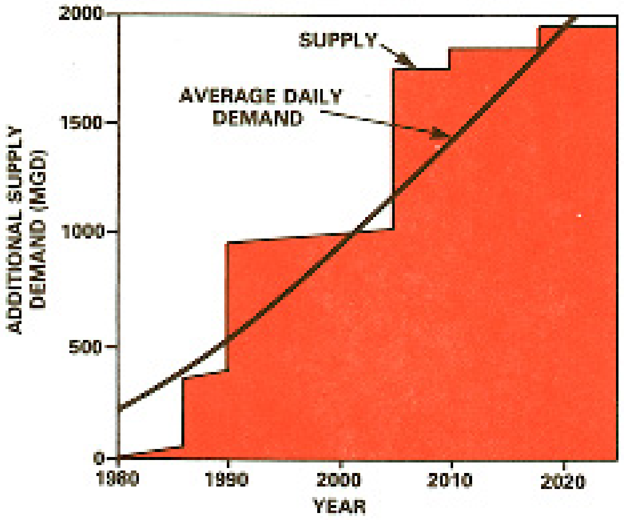
This branch illustrates an alternative near-term course of action for Connecticut, utilizing sources excluded under current state policy, and developing them to a larger, more regional extent than is typical of the state plan.

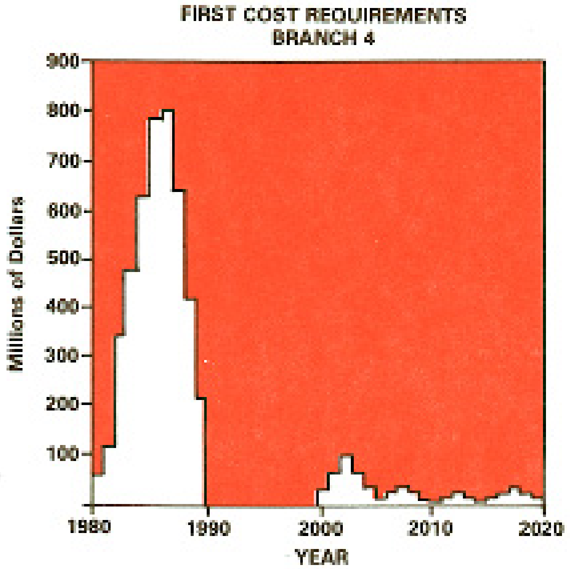
PROJECT DATA FOR BRANCH 3

PROJECT	SAFE YIELD (mgd)	FIRST COST (mill. 1975 $)	ANNUAL COST (mill. 1975 $)	COST PER MG (1975 $)
Small In-State Sources in NJ	320(1)	252	35	300
South Jersey Ground Water	165	256	26	434
Delaware Div.	265	342	42	434
Metering in NYC	50	154	16	858
Leakage Control in NYC	25	—	1	148
Domestic Cons. Device (NY)	85	—	—	—
Hudson River Project (2)	390	3,696	346	2,431
Hudson River Basin Storage	400	133	20	137
Housatonic River Power Reservoirs	100	126	16	443
Housatonic River with Konkapot	140	55	10	189

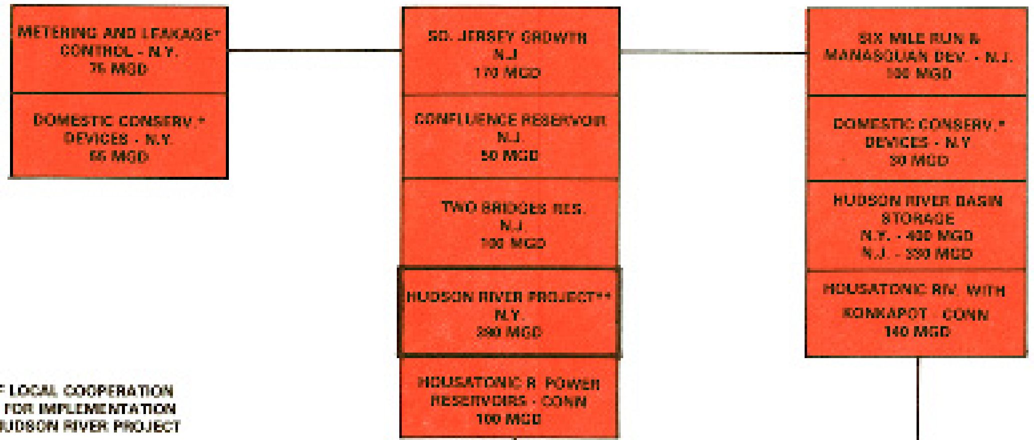
(1) Includes initial Delaware diversion of 35 mgd.
(2) Annual cost for Hudson River Project assumes amortization at 6.375% per year over 50 years.

ADDITIONAL SUPPLY, DEMAND VS. TIME
BRANCH 4





DECISION TREE - BRANCH 4



* ITEMS OF LOCAL COOPERATION REQUIRE FOR IMPLEMENTATION OF THE HUDSON RIVER PROJECT

**PROJECT RECOMMENDED IN THIS REPORT

YEAR	2000	2020
DEFICIT (MGD)	940	1,940
YIELD (MGD)	940	1,940

BRANCH 4

BRANCH NUMBER FOUR

Program Description

2000 - New Jersey's deficit of 320 mgd would be met by 170 mgd from South Jersey Ground Water, 100 mgd from Two Bridges Reservoir, and 50 mgd from Confluence Reservoir. The Hudson River Project would provide New York with 390 mgd, and Housatonic River power reservoir re-regulation would furnish the 100 mgd necessary to meet the projected deficit in Connecticut. A conservation program would provide 130 mgd for New York including Metering, Leakage Control and Domestic Conservation Devices.

2020 - In order to meet New Jersey's long run needs, Six Mile Run and the Upper and Lower Manasquan Reservoirs, providing 100 mgd, would be constructed. New Jersey could also turn to the Hudson for its additional need of 330 mgd. For New York, the Hudson Basin Storage Project would be required as well. The total increase in yield necessary would be 730 mgd. Domestic Conservation Devices would provide an additional 30 mgd for New York. In Connecticut, a further re-regulation of the Housatonic power reservoirs could provide an additional 40 mgd. The remaining 100 mgd would be provided by the construction of Konkapot Reservoir in the Housatonic Basin.

PROGRAM RATIONALE

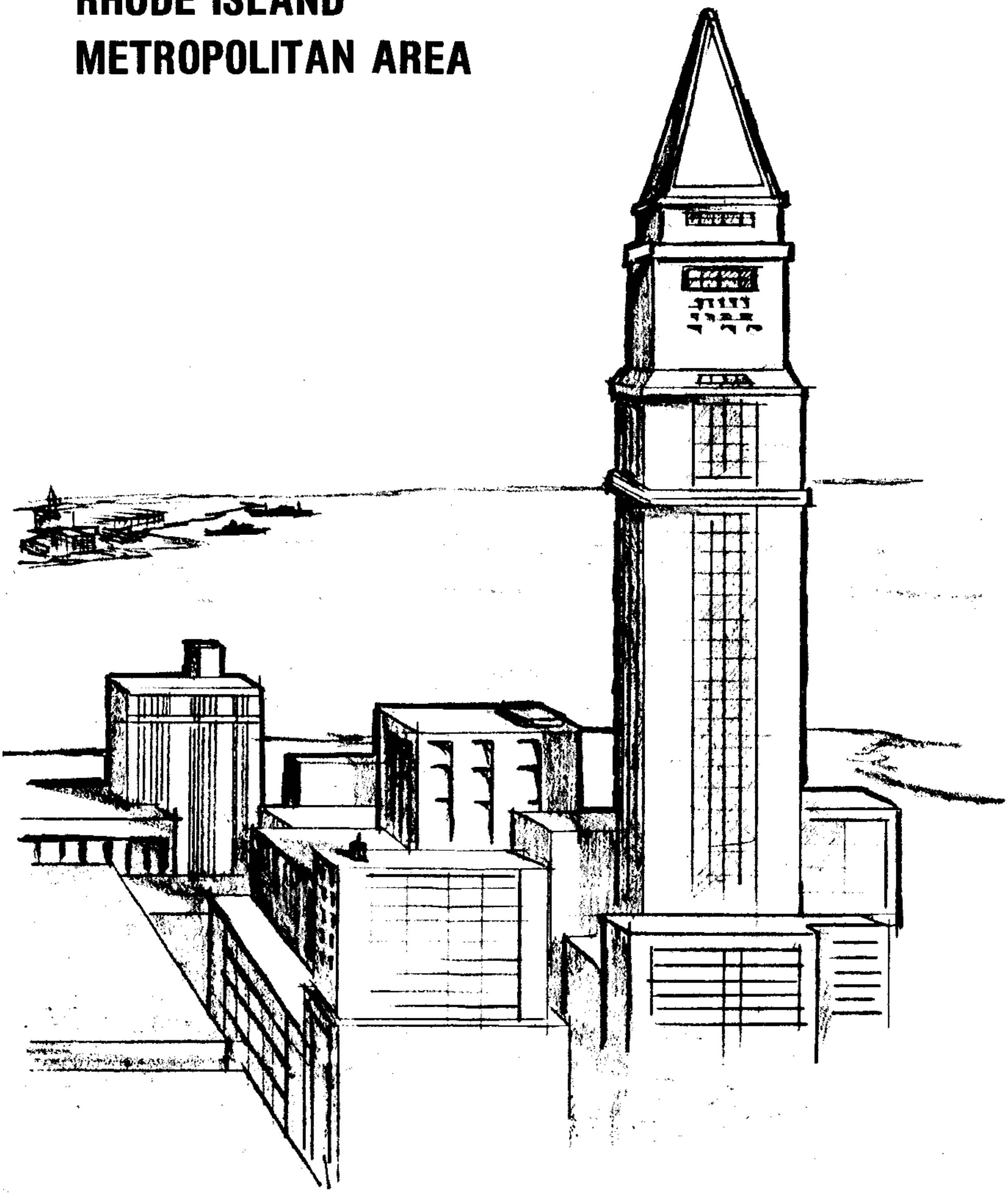
This branch presents projects that are, in general, larger and more regional in character. Such a program could face more obstacles to its implementation.

PROJECT DATA FOR BRANCH 4

PROJECT	SAFE YIELD (mgd)	FIRST COST (mill. 1975 $)	ANNUAL COST (mill. 1975 $)	COST PER MG (1975 $)
Confluence Res.	50	95	13	819
South Jersey Ground Water	170	264	27	434
Two Bridges Reservoir	100	130	18	493
Six Mile Run Reservoir	65	50	8	316
Manasquan Development	35	24	4	282
Metering in NYC	50	154	16	858
Leakage Control in NYC	25	—	1	148
Domestic Cons. Devices (NY)	85	—	—	—
Hudson River Project (1)	390	3,696	346	2,431
Hudson River Basin Storage	730	240	36	135
Housatonic River Power Reservoirs	100	126	16	443
Housatonic River with Konkapot	140	55	10	189

(1) Annual cost for Hudson River Project assumes amortization at 6.375% per year over 50 years.

CHAPTER 8
EASTERN MASSACHUSETTS-RHODE ISLAND METROPOLITAN AREA



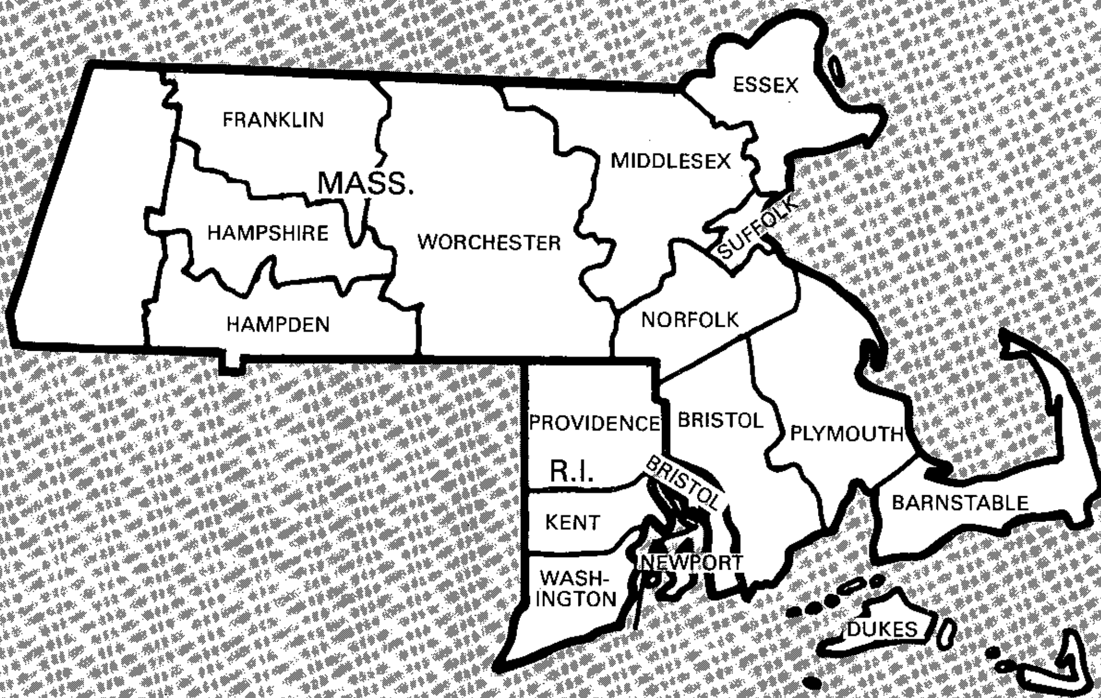


FIGURE 8-1. EASTERN MASSACHUSETTS-RHODE ISLAND METROPOLITAN STUDY AREA.

CHAPTER 8: EASTERN MASSACHUSETTS-RHODE ISLAND METROPOLITAN AREA (EMRI)

BACKGROUND

The Eastern Massachusetts-Rhode Island (EMRI) Metropolitan Area consists of the entire state of Massachusetts except Berkshire County and the entire state of Rhode Island (Figure 8-1).

The NEWS water supply planning, since its initiation in the Eastern Massachusetts-Rhode Island area, has followed a stepwise approach. In 1967 and 1968, a series of limited scope reconnaissance reports were prepared to provide an overview of the New England water supply situation. On the basis of these reports, the EMRI area was identified as a region requiring early augmentation of existing supplies.

Following completion of the reconnaissance studies and meetings with water resource officials from Massachusetts, Rhode Island and Connecticut, and the New England River Basins Commission, a feasibility study on the EMRI water supply problems was made.

The water supply feasibility study completed by the NEWS Study in late 1969 (See *Annotated List of NEWS Reports*) describes the water supply problem of the Eastern Massachusetts-Rhode Island area. It includes details on the area's water demands projected through the year 2020, and presents a number of solutions to meet them. The most urgent demand for additional water supply appeared to be in the Greater Boston and Providence Areas.

Methods of meeting these future demands were presented in the feasibility study by means of illustrative regional plans. Although illustrative, these regional plans demonstrate the predominant role which development of the Merrimack River and at least some Connecticut River water will have in meeting future water supply needs. Recognizing the role of these two major river basins in meeting future needs allowed an evaluation of the development priorities which should occur. On the basis of the analysis included in the feasibility study, early limited development of the Connecticut River Basin (to 1990) followed by later development of the Merrimack River Basin (1990-2020) appeared to offer a cost effective means of meeting the region's needs. The Boston area demand appeared to be so great as to eventually require interbasin diversions from either or both the Merrimack and Connecticut River Basins, totaling 300 mgd or more.

At a meeting to discuss the feasibility report in May 1970, Federal agencies and representatives from Massachusetts, Connecticut, Rhode Island, and the New England River Basins Commission agreed on the direction of more detailed studies. Of prime concern was the near-term (prior to 1990) water supply problem of the Eastern Massachusetts areas.

It was agreed that the Corps would study two projects in detail for diversion of less than 200 mgd from the Connecticut River Basin, investigate the use of the Merrimack River as a regional and local source of water supply, and determine the potential environmental impact of large diversions on the Merrimack and Connecticut River estuaries.

The May 1970 meeting was quite important, therefore, because it helped define the policies which would guide future water supply development within the EMRI area. Within Massachusetts this policy direction is aimed towards meeting short range needs by local surface and ground water developments, together with the Northfield Mountain and Millers River Basin projects. These developments to meet short term (1990) needs allow time to institute water conservation measures, carefully investigate Merrimack River use, and permit technological advances in such techniques as desalination and recycling which may be helpful in meeting the longer range (2020) demands.

In Rhode Island, that State has noted its preference for in-state development of its resources rather than connection to an interstate water system. Rhode Island's policy direction, therefore, follows a stage development of ground and surface water sources located principally in the Pawtuxet, Blackstone and Pawcatuck River Basins.

In 1974, reports were completed on the two Connecticut River diversion projects, Northfield Mountain and Millers River. The survey reports have been reviewed and the projects recommended for implementation by the Board of Engineers for Rivers and Harbors. Studies indicated that the projects, as finally formulated, could provide an additional 148 mgd of water supply with minimal risk of environmental damage. Further supplies could then be obtained from the Merrimack River, Ground Water (Plymouth County), and local sources.

AREA PROFILE

The EMRI area consists of Rhode Island and all of Massachusetts except Berkshire County. The region contains 357 municipalities and a population of 6.5 million. The population is expected to increase to 9.7 million by 2020. Of the current population, about 85% is urban.

The Boston area is the most significant element of the EMRI Area in terms of the demand exceeding the safe yield of existing systems. It is geographically and economically the center of the largest employment and population cluster in New England. Boston, the central city, is the Capital of Massachusetts and the most populous city in New England.

Population growth near the major metropolitan areas is expected to increase at a more rapid rate than in other sections, with the largest increases most likely to occur near the urban centers of Boston and Providence.

WATER DEMANDS

As shown in Table 8-1, the average water demand in the area in 1965 was nearly 750 mgd. This demand may reach about 1,080 mgd in 1980; 1520 mgd in 2000; and 1890 mgd by 2020. Of the expected demand, fully 75% is expected to occur in Massachusetts counties east of Worcester County. About 80% of the Rhode Island requirement will come from the counties in and adjacent to the Providence Metropolitan Area. The importance of meeting this increase in demand is underlined by the fact that 96% of the total population in the area depends upon public systems as their sole source of water supply.

The projected demand as expressed in gallons per capita per day (gpcd) varies throughout the EMRI area and is subject to high seasonal variation. In Massachusetts this demand varies from a low of 100 in Franklin County in the year 1980, rising to 162 in 2020, to a high of 312 in Dukes County in 1980 rising to 395 by 2020. In Rhode Island the least demand in 1980 is projected for Newport County, 80 gpcd, rising to 125 in 2020 while the greatest demand of 135 gpcd is forecast for Providence County in 1980, rising to 176 in 2020.

As can be seen from Table 8-1, a deficit or demand for additional water will exist in the areas as a whole in 1980. Most of the additional requirements occur in the Massachusetts portion of the area. In the Rhode Island portion deficits appear for the first time in 1980 and increase in later years. Local community deficits may appear earlier. Thus the area as a whole must be considered as one with urgent water supply problems, mainly in Massachusetts.

AVAILABLE WATER

There are 369 public water supply systems within the area with a combined safe yield of about 970 mgd, with a deficit of about 140 mgd in 1980.

The Metropolitan District Commission (MDC) of Massachusetts is the largest regional system in New England. This system supplies either all or part of the water in 42 communities including Boston. The MDC served about 2 million persons, or 37% of the Commonwealth's 1970 population.

TABLE 8-1
COMPARISON BETWEEN EXISTING OR PROJECTED DEMAND[1, 2] AND YIELD—EMRI (in mgd)

		1965	1980	1990	2000	2020
Population (Millions)	**Mass.**	5.1	6.1	6.7	7.3	8.4
	R.I.	0.9	1.0	1.1	1.2	1.3
	TOTAL	6.0	7.1	7.8	8.5	9.7
Water Demand	**Mass.**	660	953	1,140	1,349	1,674
	R.I.	89	123	147	170	219
	TOTAL	749	1,076	1,287	1,519	1,893
Yield of Existing Water Systems	**Mass.**	813	813	813	813	813
	R.I.	160	160	160	160	160
	TOTAL	973	973	973	973	973
Deficit or Over Supply	**Mass.**	(153)	133	325	536	861
	R.I.	(71)	3	20	44	59
	TOTAL	(224)	136	345	580	920

[1] Based on gpcd values by county shown in 1969 Feasibility Report and Obers Series E population projections.

[2] Deficit or over supply figures do not agree numerically with differences between Water Demand and Existing Yield due to local supplies, and an imbalance of local supply with local deficits.

MDC relies solely on surface water for its supply. Its three major reservoirs, Quabbin, Wachusett and Sudbury, impound flows in the tributaries of the Connecticut and Merrimack River Basins. Quabbin, with a capacity of 412 billion gallons, is the backbone of the system. It impounds the runoff from 186 square miles of the Swift River watershed and flow diverted from 98 square miles of the Ware River watershed, both tributaries of the Connecticut River. It appeared, until the recent occurrence of larger than normal inflows, that Quabbin could be dry by 1985 and unusable at some point before then.

Safe yield of the MDC system is about 300 mgd and average daily use in 1976 was 317 mgd. As per capita water use continues to increase and more communities join, or otherwise become dependent upon MDC, the system will be put under increasing strain. At the same time, any drought or failure in the MDC system will have severe and far reaching ramifications. Historically, surface water has been the principal source of supply for the area. Several river basins, contained either wholly or partially within the area, have potential for economical development of additional water supply sources. These potential sources are the basins of the Merrimack, Ipswich, North, Taunton, Weweantic, Pawtuxet, Blackstone, Thames, Pawcatuck and Connecticut Rivers. Together, they have a total drainage of about 18,100 square miles and an average annual runoff of 19,400 mgd.

Although the combined runoff of these River Basins appears to be enough to meet all water supply requirements, there is an acute shortage of developed facilities to tap that supply. Unfortunately major use areas do not coincide geographically with the major water sources.

The following sources were considered for development.

Connecticut River Basin

The Connecticut River Basin, with a drainage area of 11,265 square miles and an average annual runoff of 12,400 mgd is the largest in New England. The total developed yield of the Basin is only 260 mgd. The river rises in the Third Connecticut Lake in northern New Hampshire near the Canadian border. From the lake, the river flows south through New Hampshire, Vermont, Massachusetts and Connecticut for about 400 miles to its mouth on Long Island Sound at Saybrook, Connecticut. Water from the Basin has long been used for supply by Basin communities and for interbasin transfer to Boston and the surrounding area.

Merrimack River Basin

The Merrimack River Basin lies in central New England and extends from the White Mountain region of New Hampshire south to the east central region of Massachusetts. It has a total drainage area of 5,010 square miles and an average annual runoff of 4,900 mgd. In 1965, total developed yield of the Basin was only 170 mgd, with 20 mgd drawn from the mainstem.

Many tributaries of the Merrimack in the study area have been used as water supply sources, with the MDC Wachusett and Sudbury reservoirs representing the major projects.

Although the mainstem of the Merrimack has a large potential for water supply, municipalities have shunned the River because it is highly polluted with industrial and municipal waste. For many years, the only major user of the River was the City of Lawrence. Recently, however, Lowell has also begun to use the River for water supply because of the scarcity of other sources.

Similarly, as water demands increase and cleaner local sources prove inadequate, more communities, both in the Basin and beyond it, may tap the Merrimack for supply.

Available additional major storage reservoir sites within the Basin are scarce and appear expensive. However, the large flows of the mainstem itself provide an opportunity for use by direct withdrawal and treatment of high flows.

Blackstone River Basin

The Blackstone River Basin headwaters are located in central Massachusetts. From there the River flows in a generally southeasterly direction to Pawtucket, Rhode Island, and then southerly to its mouth at the Providence River. Total drainage area of the Basin is 540 square miles with an annual runoff of 59 mgd. Present water quality within the Basin is generally poor to fair. However, some small tributaries possess good quality water.

Two tributaries, Nipmuc River and Tarkiln Brook, of the Blackstone River could be developed.

Ipswich River Basin

This Basin, located on the Massachusetts North Shore, is one of a series of small coastal rivers which drain the eastern Massachusetts region. It has a drainage area of 155 square miles and an annual runoff of 160 mgd. At present, water quality within the Basin is generally good and the runoff from the Basin is heavily used for water supply purposes with the majority of supply exported from the Basin to nearby communities.

North River Basin

The North River Basin is located on the Massachusetts South Shore. At present, the river is one of the few Eastern Massachusetts basins that is relatively undeveloped. It has a drainage area of 68 square miles and an average annual runoff of 74 mgd.

Pawcatuck River Basin

The Pawcatuck River Basin is located in the southwestern part of Rhode Island and southeastern Connecticut. The watershed of the Basin totals 303 square miles with an average annual runoff of 364 mgd. Existing water quality in the Pawcatuck is generally good, although some reaches of the mainstem river are poor.

Pawtuxet River Basin

The Pawtuxet River Basin is located in the northern half of Rhode Island. The River drains an area of 230 square miles, all of which lies within Rhode Island with an average annual runoff of 290 mgd. In general, most of the Basin's streams are of good quality; however, lower reaches of the mainstem river are classified as poor. The hilly topography of the watershed has in the past lent itself to the development of water supply reservoirs, and the Providence Water Supply Board's sources are located within this River Basin.

Thames River Basin

The Thames River Basin lies principally in the eastern part of Connecticut, with portions extending into south central Massachusetts and northwestern Rhode Island.The drainage area of the Basin is 1,474 square miles with an average annual runoff of 1,658 mgd.

Present water quality in the Basin's streams range from poor to good with the Rhode Island portion of the Basin classified as good.

Taunton River Basin

The Taunton River Basin is a moderate size coastal basin that drains portions of Bristol and Plymouth Counties in southeastern Massachusetts. Its total drainage area is 543 square miles with an average annual runoff of 635 mgd. Existing water quality within the Basin varies from good in some headwater tributaries to poor in the lower reaches of the mainstem river.

Weweantic River Basin

The Weweantic River Basin is a small stream in southeastern Bristol County draining into Buzzards Bay.

Ground Water

Small yields can be developed from wells in most of the till or bedrock aquifers that underlie Massachusetts and Rhode Island. However, they would be of minor regional importance because they are capable of sustaining only relatively small yields, more suitable for local demand. There are, however, a few areas where ground water could be developed enough to make it an element in a regional scheme. The most notable of these sites are Barnstable and southeastern Plymouth Counties. In these and other regions suitable for possible ground water development, the quality of the water is quite good.

WATER SUPPLY PROGRAMS

During the planning activities in the New England area, officials and citizens in the area expressed a desire to meet water demands in concert with several additional objectives. One strong point stressed by New England officials was their desire to avoid the construction of any new reservoirs that would remove land from use, displace people, and possibly involve environmental damage. Therefore, planning in the New England area has stressed the possibility of adding to existing systems, using existing reservoirs, and capitalizing on the high spring river flows wherever possible.

Within Southeastern New England, as in the other most critical areas, planning to meet growing water demands is continuing. The planning to date, however, has revealed that the Connecticut and Merrimack River Basins, because of their size and location, could be called upon to furnish significant quantities of future water supply to the region.

As illustrated on Figure 8-3 the timing and sizing of facilities for development will depend on the branch selected. For example, if Branch 3 were selected, then critical short term demands would be largely met through development of locally available supplies. During the early time frame, very limited development of the Connecticut River Basin would be necessary. In the mid-range years, 1990-2000, locally available supplies may again furnish a major portion of the needed supply. By the long-range target years of 2000-2020, however, development of the Merrimack or possibly the Connecticut River Basins or both will probably be required to meet future water needs. Plymouth County Ground Water is an alternative to use of these Rivers. Development can be delayed or reduced if local interests can implement a demand reduction program through restrictions or water saving fixtures.

A review of branches 1 and 2 on the Decision Tree reveals dependence on the Connecticut and Merrimack River Basins as principal sources for the area's future needs. Major differences between the branches lie in the timing and scope of development for the two major river basins.

Branch 1 as one physically feasible alternative would require a commitment to large scale development of the Connecticut River Basin and Plymouth County Ground Water. Branch 2, on the other hand, would require a decision for reliance on the Merrimack River as well as Plymouth Ground Water. Branch 3, because of its dependence on locally available resources in the short to medium range target years, allows the decision regarding any requirement for further development of the Merrimack River and Plymouth County Ground Water to be made at a future date. Such a decision, of course, would have the benefit of advances in water supply technology and the latest economic and demographic trends.

The purpose of discussing the relationship of the Connecticut and Merrimack River Basins is to present the source-supply situation that NEWS investigations have revealed. It is especially important to appreciate the significance of the Merrimack and Connecticut Basins to the region when two special issues are considered.

One issue that must be considered by decision makers is Massachusetts' relationship with the State of Connecticut. This downstream state is opposed to further diversions by Massachusetts from the Connecticut River Basin. Before Massachusetts impounded the Swift River, a tributary of the Connecticut, to form Quabbin Reservoir in 1931, Connecticut brought suit to stop the diversion. The court decided in favor of Massachusetts.

Then, as now, Connecticut officials pointed out that even skimming of a limited percent of the flow might have detrimental effects on its portion of the River. Maintaining spring freshet (peak flows), according to the State Department of Environmental Protection, has benefits such as recharging ground water, replenishing of agricultural flood plain soils, flushing of sludge and silt deposits, maintaining wildlife and aquatic habitat and being a triggering mechanism for anadromous fish runs.

A second issue is the possible upstream diversion of flow by New Hampshire from the Merrimack River Basin to serve the water needs of the coastal area. No detailed proposals have been formulated by New Hampshire on this project; however, feasibility plans have been prepared. On the basis of all information gathered to date, there appear to be few alternatives to such a diversion scheme.

Because there has been no definite proposal advanced by New Hampshire, Massachusetts has not offered an opinion of such a plan. In the future, however, the Merrimack Basin may be needed as a major source of supply for Massachusetts and an allocation agreement between New Hampshire and Massachusetts will be needed.

PROJECTS CONSIDERED

Many projects were investigated and found technically feasible, as reported in the many NEWS Reports on the Region (see the *Annotated List of NEWS Reports*). Not all of these projects have been investigated to the same degree of detail, however. The projects shown in this report are illustrative, and they do reflect the region's major sources of water supply and the choices available to meet future water supply needs. These projects are summarized and organized in groups based on the source from which water is drawn.

Connecticut River Basin

Several possible methods of developing additional water supply from the Connecticut River Basin to aid in meeting the region's future water supply needs were investigated. Three of the projects considered would aid in meeting out-of-Basin needs in Eastern Massachusetts as well as portions of the in-Basin needs. All of the projects considered are high flow diversion projects. Water would be delivered through aqueduct systems for storage in the existing Quabbin Reservoir. From Quabbin, the water could then be delivered to communities principally located in Eastern Masschusetts.

• **Northfield Mountain Project.** A small portion of the annual spring runoff of the mainstem Connecticut River would be diverted to Quabbin Reservoir for use as water supply. These mainstem flows would be diverted via an existing pumped storage hydroelectric facility at Northfield Mountain, Massachusetts. The possibility of changing the pumped storage project to include water supply is currently being negotiated by electric utility officials and the Metropolitan District Commission.

Modification of the hydroelectric operating schedule to add the water supply function would consist of extending the daily pumping cycle of the 12,000 cfs reversible turbines 1.4 hours during highflow periods. This additional period is considered the idle time for the power installation between its pumping and generating cycles. The additional 375 million gallons pumped during this 1.4 hours would then be stored for water supply on top of the water stored for power generation in the Northfield Mountain pumped storage reservoir.

The additions required to develop the project for water supply would consist of additional storage in the power pool; an 8.5-mile, 10-foot-diameter connecting tunnel to Quabbin Reservoir; disinfection units and minor appurtenant structures. The estimated safe yield of this project is 72 mgd.

• **Millers River Basin Project.** This project would divert water by highflow skimming from the Millers River Basin, a tributary of the Connecticut River, which lies generally north of Quabbin Reservoir. An 8-foot-diameter tunnel would be built from the existing Tully Flood Control Dam and Lake to carry the withdrawn high flows from the Tully River to the Millers River. At the Millers River above Athol, Massachusetts, an intake would divert the water from the Millers to a 10-foot-diameter, 9.5-mile tunnel to Quabbin Reservoir. Because water in the Millers is presently heavily polluted, this project includes waste treatment plants upstream from the river intake. This project would provide an additional 76 mgd of safe yield to the Quabbin Reservoir system.

• **Connecticut River Diversion (500 mgd).** The project that could be constructed would high flow skim water from the mainstem Connecticut near Hadley, Massachusetts. Water withdrawn would be delivered to Quabbin, via pumping through a 26-foot-diameter tunnel 9.8-miles-long. A new tunnel 24.2 miles long, would connect the Wachusett and Quabbin Reservoirs. From Wachusett, a new 14.1-mile-tunnel may be needed to connect to the existing aqueduct system. Quabbin Reservoir might require some enlargement.

Merrimack River Basin

Two of the projects investigated which would develop resources of the Merrimack River Basin are included in programs developed. The service areas vary from municipalities near the River to out-of-Basin areas in eastern Massachusetts. The Projects are interchangeable and are therefore not separately identified in Figure 8-3.

• **Merrimack River High Flow Skimming.** This project would divert flow from the Merrimack when river flow is in excess of other water resource requirements, such as that needed for established water quality standards. Withdrawal from the river would be used to maintain maximum storage in Quabbin and Wachusett Reservoirs. During high flow periods in the Merrimack River, water demands within the consumer area would be met partially or wholly by diversions from the Merrimack River. During low flow periods, when flows are lower than those necessary for allied water resources uses, no diversions would be made from the Merrimack. During such periods, water supply needs would be met by drawing water from Quabbin and Wachusett Reservoir storage. This project reduces upstream storage reservoir requirements and would yield 210 mgd.

• **Merrimack River Continuous Withdrawal.** This project would use the Merrimack River as a water supply source on a year-round basis. In this plan, water would be diverted, treated and delivered daily. During periods of low flow, water would have to be released from upstream reservoirs to compensate for the low flow withdrawals. This continuous withdrawal method would also yield 210 mgd.

In order to fully develop yield from either project, needed facilities would include intake works on the Merrimack River, a major water treatment plant and 92 miles of varying diameter tunnel within the Boston Metropolitan complex and a connecting 14-mile tunnel aqueduct from Wachusett Reservoir to the transmission aqueduct loop. If continuous withdrawal were used then several upstream reservoirs would also be required.

Ipswich River Basin

• **Ipswich River Project.** In this project, the Ipswich River would be further developed by high flow skimming from the mainstem to an off-stream reservoir. The available yield is estimated to be 25 mgd. This project would require construction of an off-stream reservoir, diversion aqueducts, a pumping installation, a water treatment plant and a force main connecting the reservoir to the treatment plant.

Taunton River Basin

• **Taunton River Diversion.** The project would skim the high flows of the Taunton and deliver it to off-stream storage facilities.

One method would divert water from the Taunton to existing storage at the Lakeville Ponds complex. The second method would deliver diverted flows to a proposed reservoir site, known as Copicut Reservoir.

Water from either of the off-stream storage sites would be treated and delivered via transmission facilities to communitites in southeastern Massachusetts. Potential yield would be 25 mgd.

• **Taunton Estuary.** Further development of the Taunton could be accomplished by construction of a dam and reservoir in the lower reaches of the River. The site selected for this project is located near the river mouth within the tidal estuary portion of the Basin. This facility would yield about 97 mgd for Bristol County, Massachusetts and perhaps portions of Rhode Island.

Weweantic River Basin

• **Weweantic River Diversion.** Diversion of flow from the Weweantic River to the existing Lakeville Ponds storage complex has been proposed as an early action project for the New Bedford-Fall River-Taunton, Massachusetts, metropolitan area. This diversion would provide 15 mgd for that region.

Pawtuxet River Basin

• **Big River Reservoir.** The project would develop the Big River watershed for 29 mgd by construction of a dam and storage reservoir on the mainstem of the River. Water drawn from storage would be treated and conveyed via force mains to existing transmission lines of the Providence system.

Construction of the Big River dam would provide 82,000 acre-feet of additional storage. Water drawn from the reservoir would be conveyed in a 1.1-mile 90-inch-conduit to the water treatment plant. Finished water from the treatment plant would be conveyed to existing transmission mains through a 4.5-mile, 84-inch-diameter pipe and a 2-mile 10-foot-diameter tunnel.

• **Flat River.** The adjoining watershed, Flat River, has limited storage sites and transfer of water from the Flat River via high flow withdrawal could increase the dependable yield of Big River Reservoir. Additional yield from this project is estimated to be 13 mgd.

Thames River Basin

• **Moosup River Diversion.** Development of the Thames River Basin within Rhode Island would consist of high flow withdrawals from the Moosup River to a small regulating reservoir and then to Big River Reservoir.

The major components of the Moosup River diversion would consist of a diversion dam on the Moosup and pumping facilities with connecting aqueduct to the Big River Reservoir to develop a yield of 20 mgd.

Pawcatuck River Basin

• **Wood River Project.** The project investigated in the Pawcatuck River Basin would develop a tributary, the Wood River. The Wood development, an alternative to the Moosup project described earlier, would flood skim and deliver water to the Providence area via the Big River Reservoir.

The major components of the Wood project are an initial diversion dam and intake structure, pumping facilties and a connecting aqueduct from the intake to the Big River watershed. Eventually, as demand increases, a dam and reservoir could be built to develop the maximum potential of this source.

Flow would be diverted from the Wood through a 4.2-mile, 48-inch-diameter pipeline to the Big River Reservoir. The additional yield would be 19 mgd. If a 13,500 acre-foot reservoir was ultimately added to the system, the Wood River system total yield would be 30 mgd.

Blackstone River Basin

• **Nipmuc and Tarkiln Reservoirs.** Two tributaries, the Nipmuc River and Tarkiln Brook, of the Blackstone River would be developed for a combined yield of 14 mgd. The area to be serviced by these projects would be northern Rhode Island.

The projects would develop Tarkiln Brook by construction of a dam and reservoir, pumping facilties and a connecting aqueduct from the reservoir to a water treatment plant. Initially, additional yield from the Nipmuc River would be made available by high flow withdrawals. As water demands increase, construction of a storage dam and reservoir on the Nipmuc itself would allow the development of the project's full potential yield.

In the operation of this project, water would be diverted from the Nipmuc and delivered to a reservoir on Tarkiln Brook through a 4.3 mile, 30-inch-diameter conduit. Water from the reservoir would be treated and conveyed 12 miles through pipelines to major distribution points.

Sudbury River Basin

Subsequent to the Sudbury River Act of 1872, a series of seven reservoirs controlling the 75.2 miles of drainage area were constructed to develop the watershed for water supply for the Boston water system. In 1947, in response to the availability of higher quality supply from Quabbin Reservoir, four of the Sudbury reservoirs were converted to recreational usage and their water supply use discontinued. Due to the need for additional water supply in the future, the potential of redeveloping the complete Sudbury River System as a source has been considered.

• **Sudbury River Projects.** Four alternative redevelopment plans have been formulated through a study sponsored by the Metropolitan District Commission. These are: continue operation of the system as at present with the addition of water treatment; redevelop the system with a high flow skimming operation; redevelop the system to maximize water supply with downstream release limited to the current legislated amount; redevelop the system for recreational purposes. Available water from the first three alternatives ranges from 1.5 to about 51 mgd. The last redevelopment alternative would not include augmentation of water supply as a purpose.

Southeastern Massachusetts and South Central R.I. Gound Water

An investigation of the potential ground water resources was conducted by the United States Geological Survey (USGS) as input to the NEWS Study. In their analysis, the USGS did not undertake any new gound water research, but made use of available data from prior reports.

The USGS analysis outlined two regions that may possess sufficient gound water resources for regional supply. In Southeastern Massachusetts and South Central Rhode Island, the studies indicate that up to 300 mgd could be developed. Other areas were identified as having potential ground water sources capable of meeting local requirements.

The ground water aquifer of Southeastern Massachusetts lies within the watersheds of a number of small coastal streams. Available data indicate that ground water quality is generally good. However, the area has a history of iron and manganese increasing in concentration in existing wells over a period of time and treatment may be necessary.

• **Ground Water 12 mgd.** One project would develop and supply an average yield of 12 mgd to the northern portion of Plymouth County, Massachusetts. Necessary facilities include well fields, pumping stations, transmission mains from well fields to municipalities, and water treatment plants. The water would be transported through a 36-inch-diameter conduit, 23 miles to Northern Plymouth County.

• **Bristol County Local Development.** A second project would develop 28 mgd for municipalities in Bristol County. Facilities needed include well fields, booster pumping stations, water treatment plants and connecting transmission aqueducts to communities. The water would be delivered through 30 miles of varying diameter pipelines.

• **Plymouth County Ground Water.** A regional project for the Eastern Massachusetts area would develop 210 mgd in Plymouth County. Major items necessary for this development include 210 gravel packed wells; a collection manifold system; facilities for iron and manganese removal; a 35 mile, 8 foot diameter transmission pipeline to the nearest existing regional aqueduct and high lift pumping stations to supply the necessary head for conveyance of the supply. In order to convey the supply within the service area, additions to the existing regional aqueduct system may also be necessary. These include the construction of 1.8 miles of a second aqueduct from Shaft C to Shaft 1 of the existing MDC system and a connecting 1 mile, 10 foot diameter tunnel from the Weston to the Norumbega Reservoir with a pumping station. The project would require approximately 4,800 acres or about 7.5 square miles of land.

• **Rhode Island Ground Water.** The ground water from the upper Pawcatuck River Basin has the potential of meeting the demands of South Central Rhode Island as well as the two islands of Jamestown and Newport. Development of 11 mgd from well fields located on the mainland could be piped to existing systems on the islands.

In this project, water would be conveyed by two 20-inch mains from the wellfield to a collection point. A 24-inch transmission main would carry the water 14 miles to the Jamestown-Newport water distribution system.

Local Development

Several communities within Massachusetts are anticipating the need for additional supplies by 1990. In these instances, the communities have determined that development of locally available resources will allow them to meet their short term needs and they are moving toward development of these sources. For example, in the Brockton Metropolitan area and surrounding municipalities, development of local ground water supplies and diversion of flow from a number of small coastal streams to the existing Silver Lake System is expected to yield adequate supplies through 1990 for these south shore communities. Because of the diversity and number of the local projects, capital costs, annual operation and maintenance costs and necessary decision timing are not included in the sections that follow. Approximately 100 mgd can be developed in the western Massachusetts counties and Dukes, Nantucket and Barnstable. Other areas of Massachusetts and Rhode Island can develop up to about 260 mgd.

Water Conservation

• **Demand Modification.** Based on present knowledge and the particular characteristics of the EMRI Area, the most promising demand reduction technique is considered to be a consumer education program combined with installation of water saving appliances (water saving toilets and inserts and shower heads) in new or replacement dwelling units. If implemented by local interests, this combination of techniques could reduce the estimated long term demand requirements and could represent an important increment in the region's plan.

DECISION TIMING

The timing involved for implementation of each project is an important factor to consider when selecting projects for inclusion in a program. The schedules of implementation shown in Figure 8-2 are for those early action projects in each branch of the Decision Tree. Figure 8-2 illustrates the point in time at which project decisions should be made.

The Connecticut River Diversion of 500 mgd, is one alternative for meeting the needs of the Metropolitan Boston region. It is shown in the Table because it involves a long lead time from approval to completion of construction. Therefore, even assuming that project approval could be secured by 1978, the project could not be operational until about mid-1993.

Big River Dam is required about 1981, according to state officials, in order to maintain an adequate supply reserve. In order to meet the 1981 target date, necessary approvals should have been secured by 1972. Since they were not, the earliest the project can now come on line, given approval in 1978, is 1987.

Local Ground Water according to latest estimates would meet needs developing after 1990. To have these projects on line when required, necessary approvals would have to be secured by 1981 at the latest.

Plymouth County Ground water up to 150 mgd, even with timely local funding, should be approved by 1978 to permit construction of well fields, pumping station and connecting pipelines to the MDC system by 1990.

Taunton River Diversion, could be supplying 25 mgd by 1987 if approval were secured by 1978.

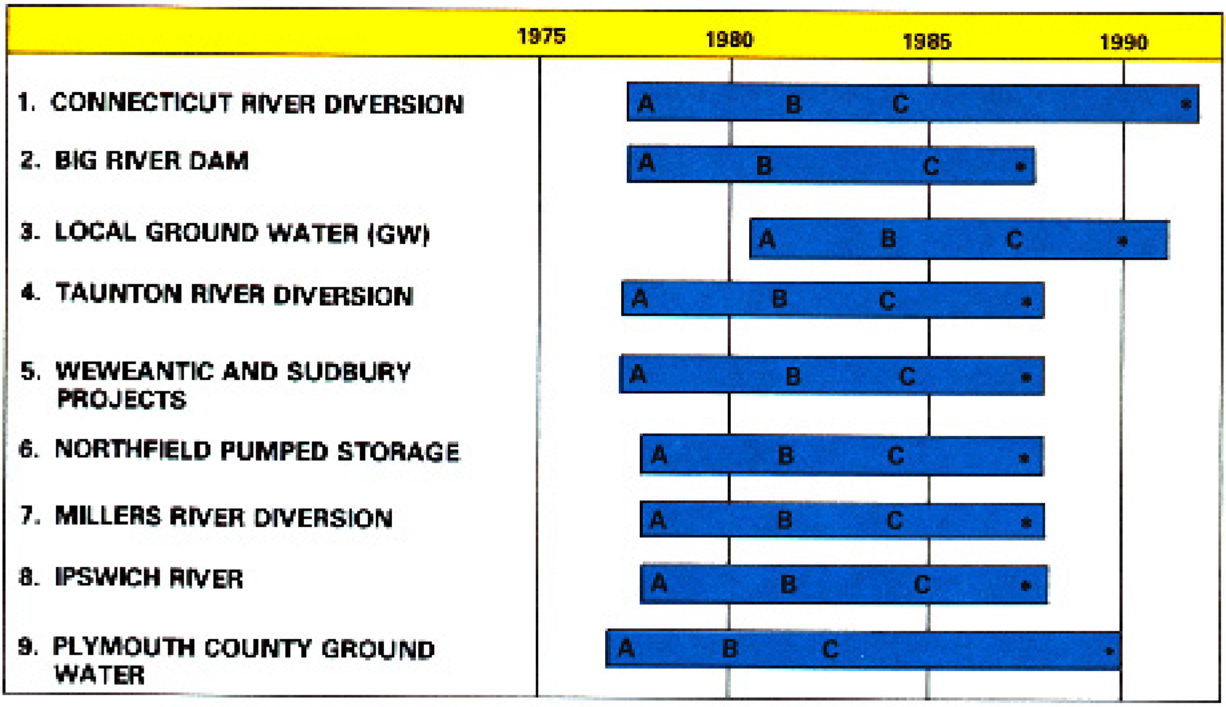


FIGURE 8-2. DECISION TIMING FOR INTITIAL PROJECTS-EMRI

LEGEND

A PROJECT APPROVAL
B FUNDING FOR ENGINEERING DESIGN
C FUNDING FOR CONSTRUCTION

*PROJECT ON LINE

"Weweantic River Diversion", has been recommended by the area's regional planning agency as a means to allow the New Bedford-Fall River-Taunton, Massachusetts, metropolitan area to meet its anticipated 1990 supply needs. Approval would be required by 1978 to have the project on line by 1988. Timing for the Sudbury Project would be the same.

Northfield and Millers River projects are designed to help to meet the short term needs of the Metropolitan Boston region. They have been endorsed by the Commonwealth of Massachusetts. They have also been approved and recommended for construction by the Board of Engineers for Rivers and Harbors. If final approvals can be secured in 1978, the projects could be operational in 1987.

The Ipswich River project is presently under investigation by Massachusetts State officials. If approvals are forthcoming in 1978, the project could come on line in 1987.

PLANNING ASSUMPTIONS

Planning in the area has been keyed to a strong desire by officials and citizens to avoid any new reservoir construction.

Three alternative water supply programs for the EMRI area, reflecting views voiced by area citizens and officials, have been formulated as shown in Figure 8-3 and were developed on the basis of the following assumptions:

1. An urgent water supply need exists and the deficit will get larger.

2. Water supply projects will be necessary despite use of water saving fixtures or appliances.

3. Water supply sources should be developed to meet the base load demand rather than peak demands.

4. Water use restrictions will be of limited value in reducing base load demand.

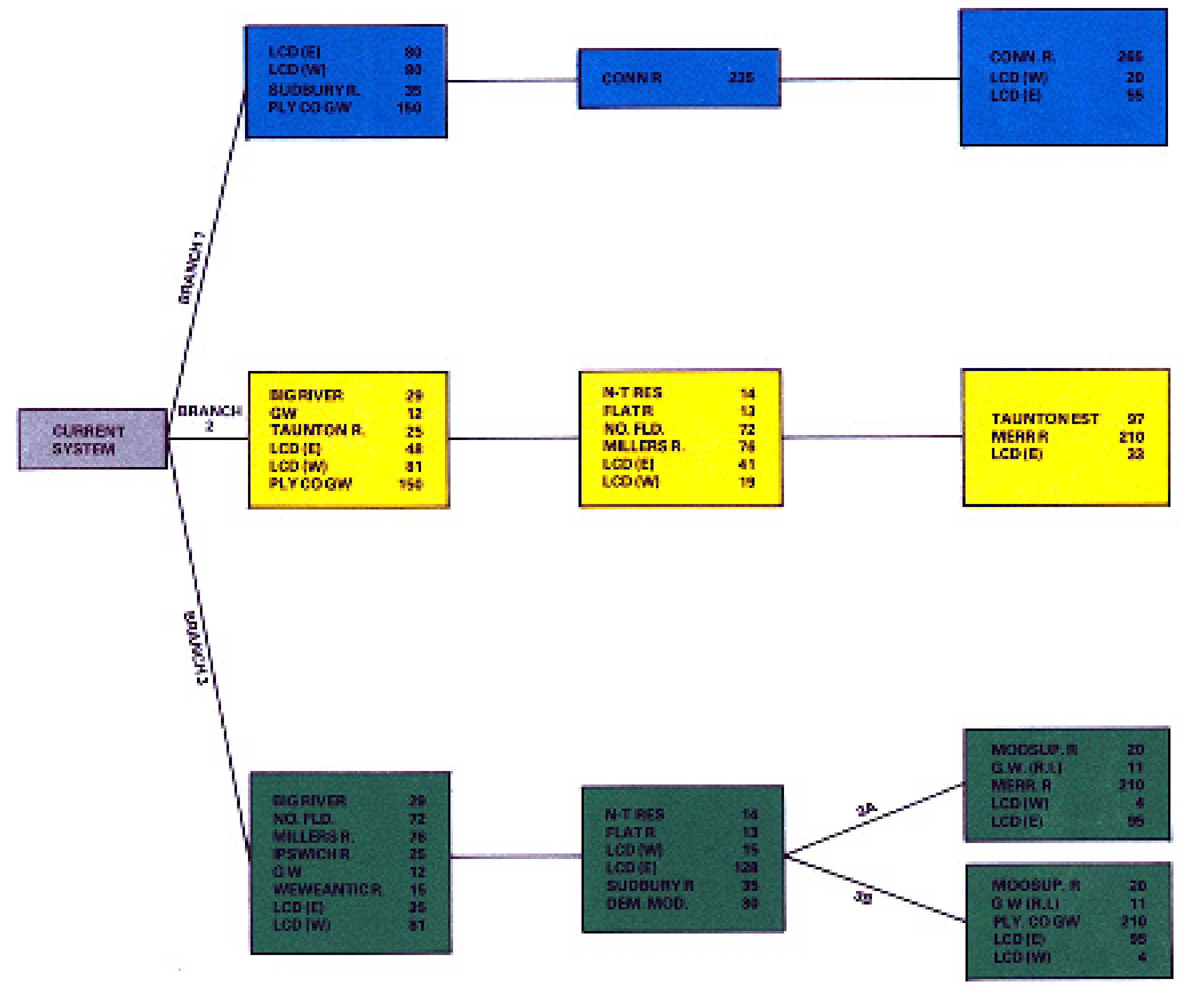
COSTS

First costs have been shown on the Project Data Tables for each branch for each project based on the Engineering News Record Construction Cost index of 2300. (January 1976) Interest and amortization have been calculated at an estimated local bonding rate of 7 percent over 35 years. OM & R costs as well as the interest and amortization have been shown on an annual basis so as to represent one year's cost after a project is on line.

Northfield and Millers River Projects are shown with first costs updated to March 1977 price levels. Since these projects have been recommended for Federal authorization, the current Federal interest rate of 6⅜ percent and a 50 year amortization period were used to compute annual costs.

FIGURE 8-3 DECISION TREE EMRI PROJECTS

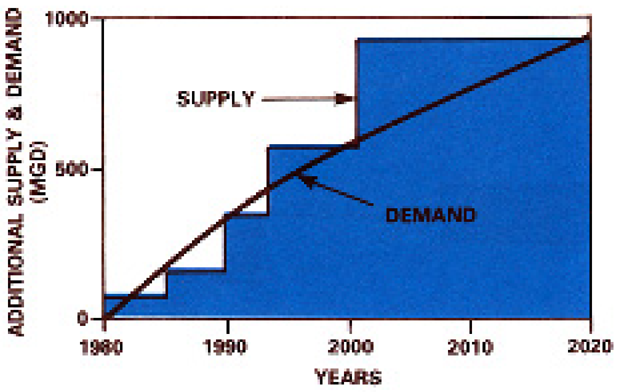
LEGEND:
GW - GROUND WATER (WELLS)
LCD (W) - LOCAL DEVELOPMENTS IN WESTERN MASSACHUSETTS COUNTIES AND THE COUNTIES OF NANTUCKET, DUKES AND BARNSTABLE
LCD (E) - LOCAL DEVELOPMENTS IN EASTERN MASSACHUSETTS
N-T RES. - NIPMUC AND TARKILN RESERVOIRS
EST - ESTUARY WATER TREATMENT PLANT
PLY CO GW - PLYMOUTH COUNTY GROUND WATER
DEM. MOD. - DEMAND MODIFICATION

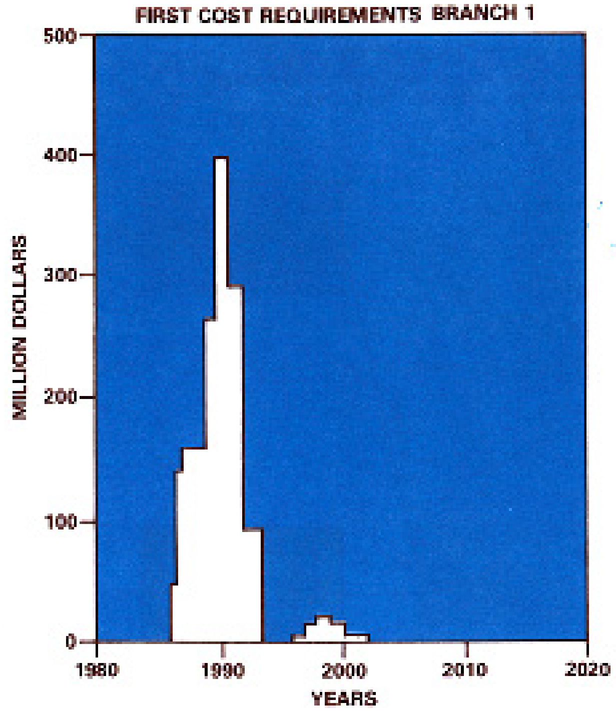


BRANCH	THROUGH 1990 ADDITIONAL[1] DEMAND 345 MGD		THROUGH 2000 CUMULATIVE ADDITIONAL[1] DEMAND 580 MGD		THROUGH 2020 CUMULATIVE ADDITIONAL[1] DEMAND 920 MGD	
	ADDITIONAL SUPPLY (MGD)	TOTAL ANNUAL COSTS ($ MILLIONS)	CUMULATIVE ADDITIONAL SUPPLY (MGD)	TOTAL ANNUAL COSTS ($ MILLIONS)	CUMULATIVE ADDITIONAL SUPPLY (MGD)	TOTAL ANNUAL COSTS ($ MILLIONS)
1	345	26.47	580	135.32	920	146.96
2	345	37.00	580	52.39	920	119.71
3A	345	31.09	580	40.77	920	97.40

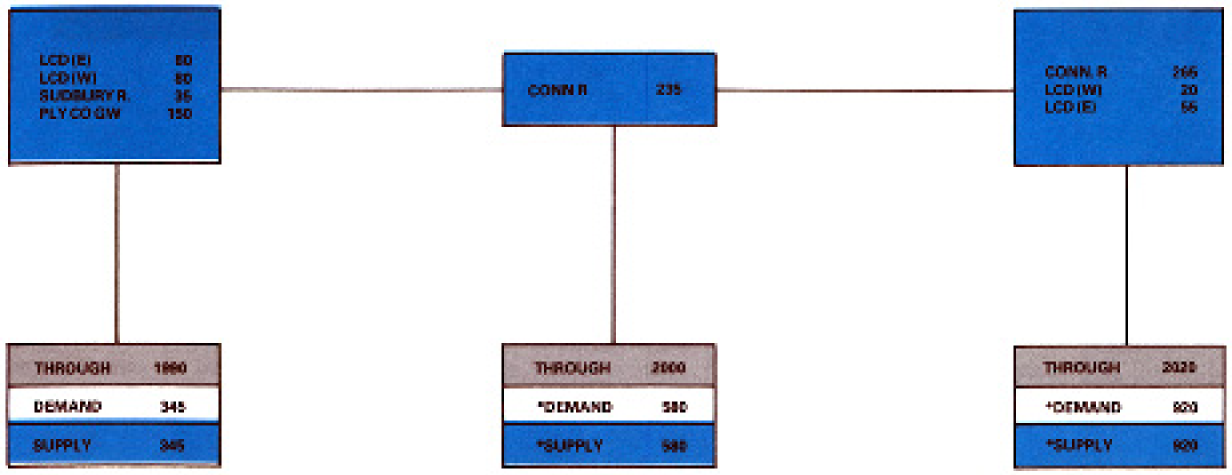
[1] Additional demand to be met by new projects shown as deficits in table B-1.

ADDITIONAL SUPPLY DEMAND VS. TIME
BRANCH 1



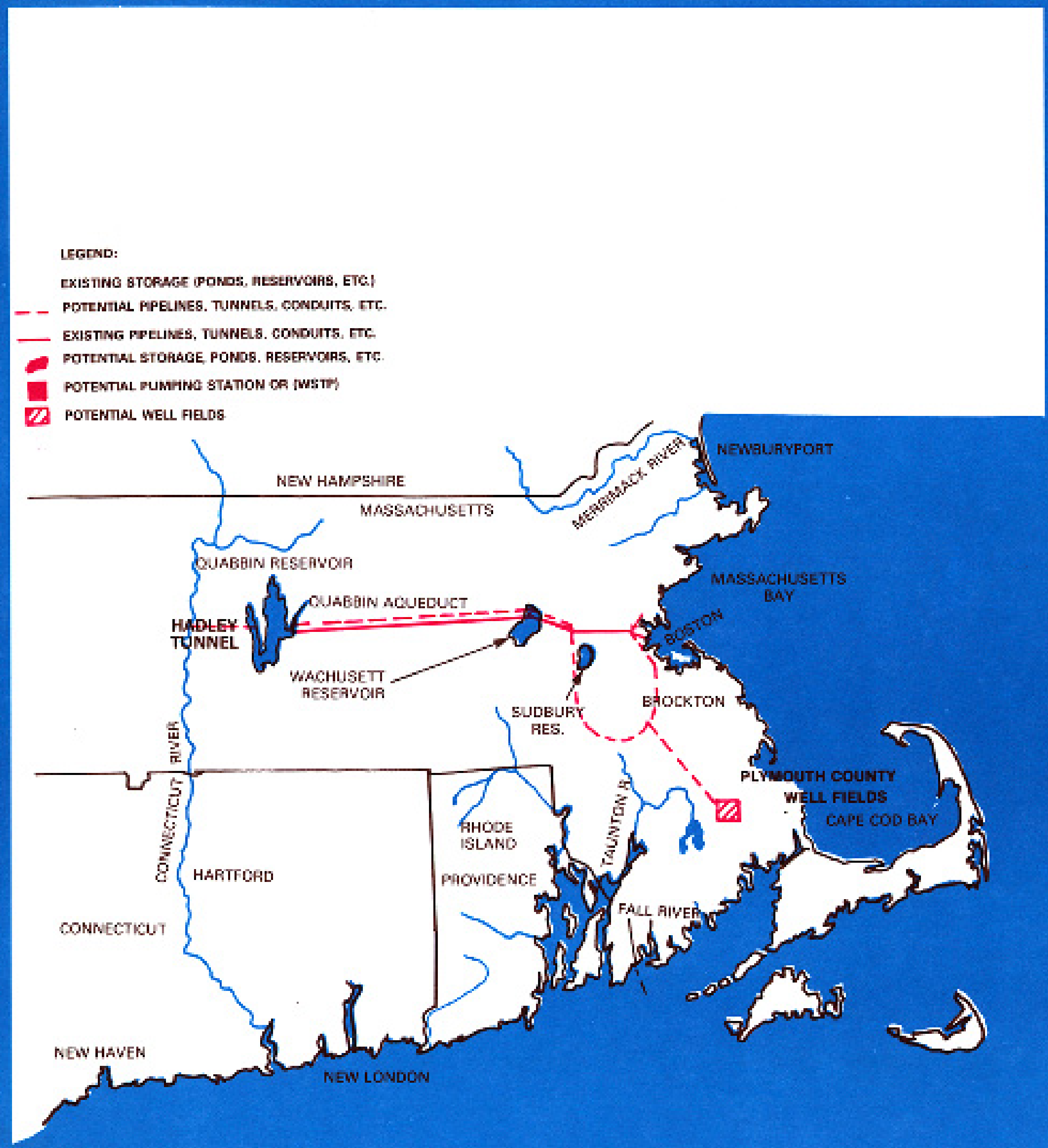


DECISION TREE - BRANCH 1
ALL AMOUNTS IN MGD



*CUMULATIVE ADDITIONAL

BRANCH 1



BRANCH NUMBER ONE

PROGRAM DESCRIPTION

Through 1990, development of 80 mgd through local projects in the Western Massachusetts counties and in Dukes, Nantucket and Barnstable Counties will meet the needs of those areas. For Eastern Massachusetts, supplies will have to be provided through numerous small local developments. Approximately 80 mgd can be developed from these sources by 1990. Plymouth County ground water may supply 150 mgd and redevelopment of the Sudbury 35 mgd. For the 1990-2000 time period, 235 mgd of a possible 500 mgd diversion from the Connecticut River, could be provided. Although all the larger tunnels and pump stations would be built in the early time frame, a portion of the facilities and operating costs would be deferred until needed.

For the 2000 to 2020 time period the remaining 265 mgd yield from the Connecticut River project would be supplemented by local developments totaling 75 mgd.

PROGRAM RATIONALE

The Branch 1 program emphasizes reliability of supply to meet demand in the mid-range time frame.

The program is intended to show one way in which the largest potential source of surface water in the basin could be used. The diversions required would take place only when flows in the Connecticut were high and therefore, the river would retain potential for downstream use.

Because of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500), quality in the river is expected to improve in the future and health risks will be reduced.

There is, however, a risk related to the timeliness with which this project could be implemented due to the objection of the State of Connecticut to diversions from the Connecticut River Basin. As noted earlier in this report, jurisdictional questions often require lengthy periods of time to resolve. Jurisdictional questions may also delay use of extensive well fields such as those in Plymouth County.

Branch 1 offers little opportunity to build the major elements, i.e., the transmission, lines, as modular units. It is inefficient to construct tunnels and major pipelines at intervals of less than 20 to 25 years. Therefore, a long term commitment must be made to the use of the Connecticut River project once it is implemented if proper efficiencies are to result. The inhabitants of Western Massachusetts seem to prefer that the Greater Boston Metropolitan Area develop water supplies either within its boundaries or closer than the Connecticut River Basin. The MDC already diverts 195 mgd from the Connecticut Basin through the Quabbin Reservoir System. Therefore, questions of equity are being raised over increased diversions from the Basin.

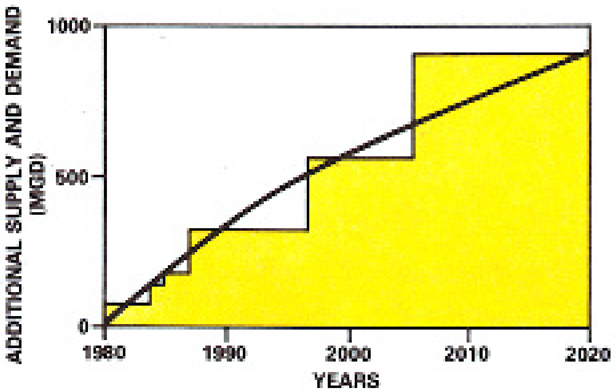
The primary advantage of this branch is that large scale development of the Connecticut River would insure an adequate supply of water for the mid-range future.

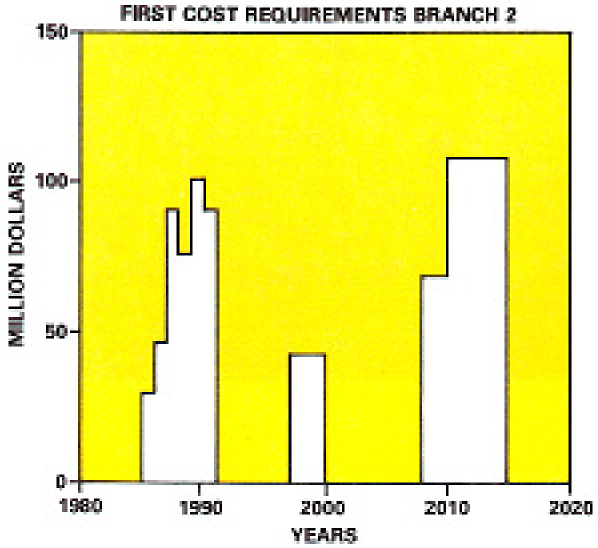
PROJECT DATA FOR BRANCH 1*

PROJECT	ULTIMATE SAFE YD. MGD	FIRST COST* $ MILLIONS	ANNUAL COST $ MILLIONS				
			INT. & AMORT.	OM & R	THROUGH 1990	THROUGH 2000	THROUGH 2020
SUDBURY R.	35	52.57	4.06	1.00	5.06	5.06	5.06
G.W.	150	208.71	13.94	7.47	21.41	21.41	21.41
CONN. RIVER	500	1347.07	104.04	16.45	0	108.85	120.49
LCD (E)	135	—	—	—	—	—	—
LCD (W)	100	—	—	—	—	—	—
TOTAL	920	1608.35	122.04	24.92	26.47	135.32	146.96

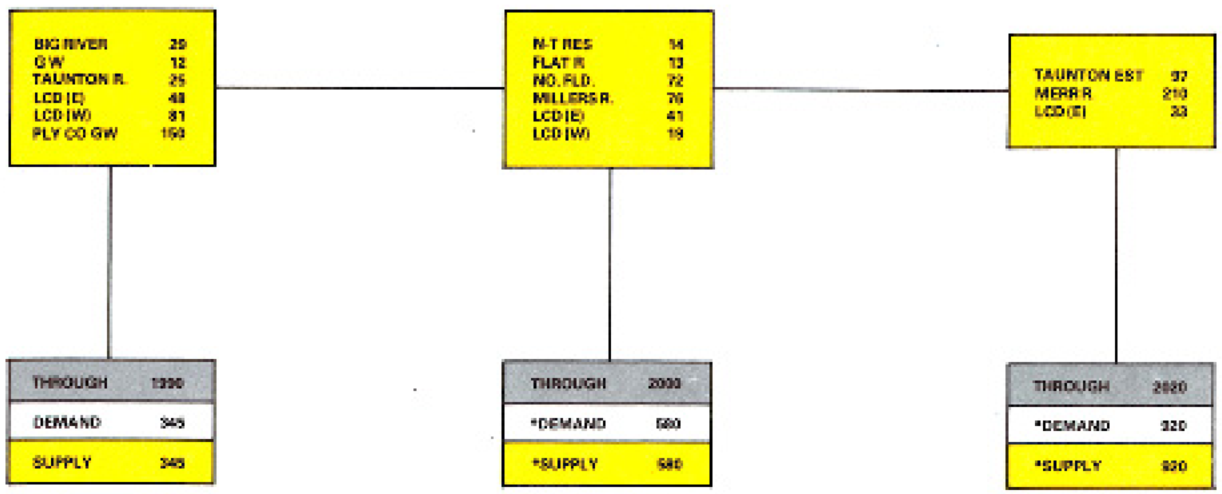
*ALL FIGURES BASED ON ENGINEERING NEWS RECORD CONSTRUCTION COST INDEX OF 2300
LOCAL DEVELOPMENT COST (E) AND (W) ARE NOT INCLUDED

ADDITIONAL SUPPLY DEMAND VS. TIME BRANCH 2



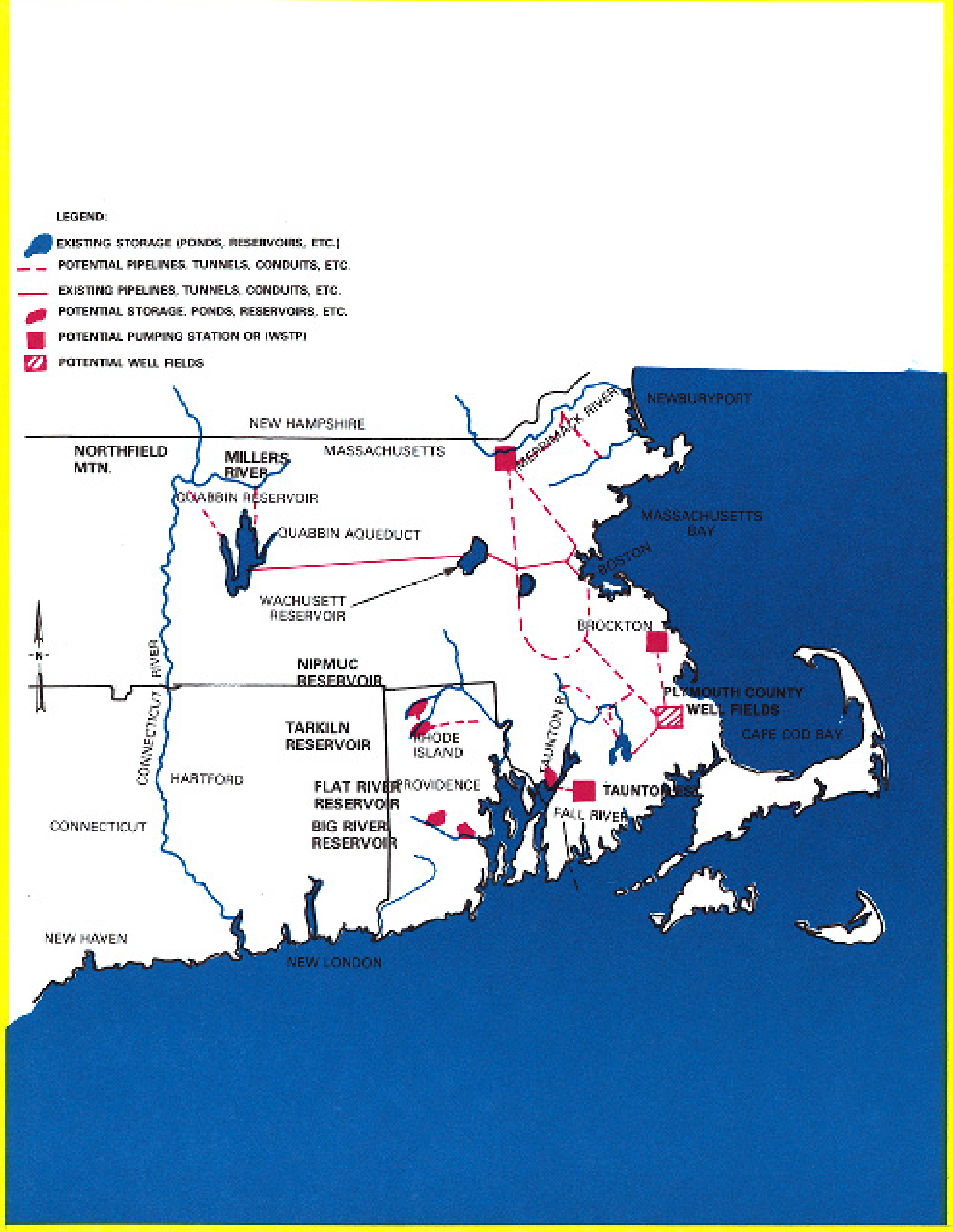


DECISION TREE - BRANCH 2 ALL AMOUNTS IN MGD



*CUMULATIVE ADDITIONAL

BRANCH 2



BRANCH NUMBER TWO—

PROGRAM DESCRIPTION

Six projects are proposed for the 1980 to 1990 decade: Plymouth County Ground Water would be developed up to 150 mgd; local ground water would yield 12 mgd; diversion of high flows from the Taunton River with storages in existing ponds would yield 25 mgd; development of local resources in Western Massachusetts and Dukes, Nantucket and Barnstable Counties would add 81 mgd; locally developed supplies in the Eastern Massachusetts area would total 48 mgd by 1990; and the Big River project in the Pawtuxet River Basin would yield 29 mgd. The total yield would be 345 mgd.

For the 1990-2000 time period requirements would be met by pumped storage from Northfield Mountain providing 72 mgd; diversions from the Millers River for 76 mgd; local development in Eastern Massachusetts would provide an additional 41 mgd; Western Massachusetts, Dukes, Nantucket and Barnstable Counties an additional 19 mgd; the Nipmuc River and Tarkiln Brook Reservoirs would yield 14 mgd; and the Flat River development 13 mgd.

Beyond 2000 the Merrimack River would be developed for 210 mgd by continuous withdrawal or high flow skimming, the Taunton Estuary developed for 97 mgd and local development for 33 mgd.

PROGRAM RATIONALE

Branch 2 is an alternative which could be implemented if (a) development of the Northfield and Millers River projects was to be delayed to the 1990-2000 time period, and (b) no additional major Connecticut River diversions were to be included for the region. It is intermediate between the other two branches in cost.

PROJECT DATA FOR BRANCH 2*

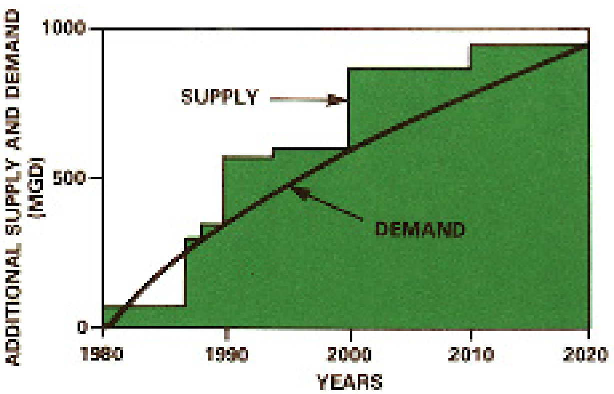
PROJECT	ULTIMATE SAFE YD. MGD	FIRST COST* $ MILLIONS	ANNUAL COST $ MILLIONS INT. & AMORT.	OM & R	THROUGH 1990	THROUGH 2000	THROUGH 2020
BIG RIVER	29	61.55	4.75	1.39	6.14	6.14	6.14
GROUND WATER	12	29.57	2.28	1.20	3.48	3.48	3.48
TAUNTON R.	25	55.86	4.31	1.66	5.97	5.97	5.97
PLY CO G.W.	150	208.71	13.94	7.47	21.41	21.41	21.41
N-T RESERVOIR	14	32.64	2.52	.58	0	3.10	3.10
NORTHFIELD (1)	72	55.94	4.09	.91	0	5.00	5.00
FLAT RIVER	13	11.39	.88	.64	0	1.52	1.52
MILLERS R. (1)	76	61.35	4.49	1.28	0	5.77	5.77
TAUNTON EST.	97	131.98	10.19	5.02	0	0	15.21
MERRIMACK RIV.	210	542.14	41.87	10.24	0	0	52.11
LCD (W)	100	—	—	—	—	—	—
LCD (E)	122	—	—	—	—	—	—
TOTAL	920	1191.13	89.32	30.39	37.00	52.39	119.71

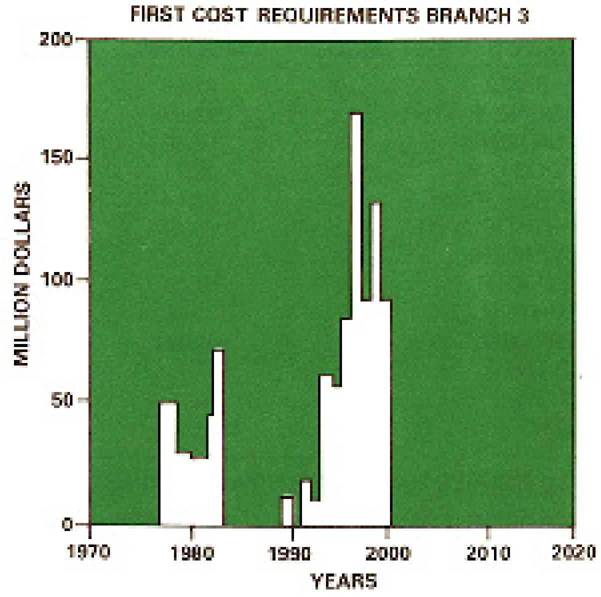
*ALL FIGURES BASED ON ENGINEERING NEWS RECORD CONSTRUCTION COST INDEX OF 2300

(1) NORTHFIELD AND MILLERS RIVER PROJECTS ARE SHOWN WITH FIRST COSTS UPDATED TO MARCH 1977 PRICE LEVELS AND ANNUAL COST AT THE FEDERAL INTEREST RATE of 6.375 PERCENT OVER 50 YEARS.

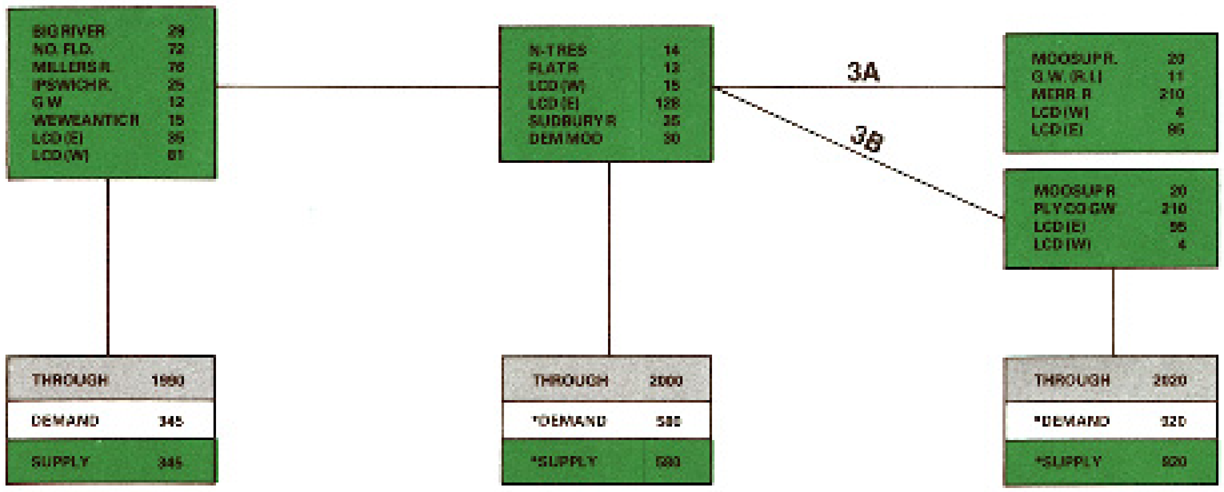
LOCAL DEVELOPMENT COST (E) AND (W) ARE NOT INCLUDED

ADDITIONAL SUPPLY DEMAND VS TIME BRANCH 3



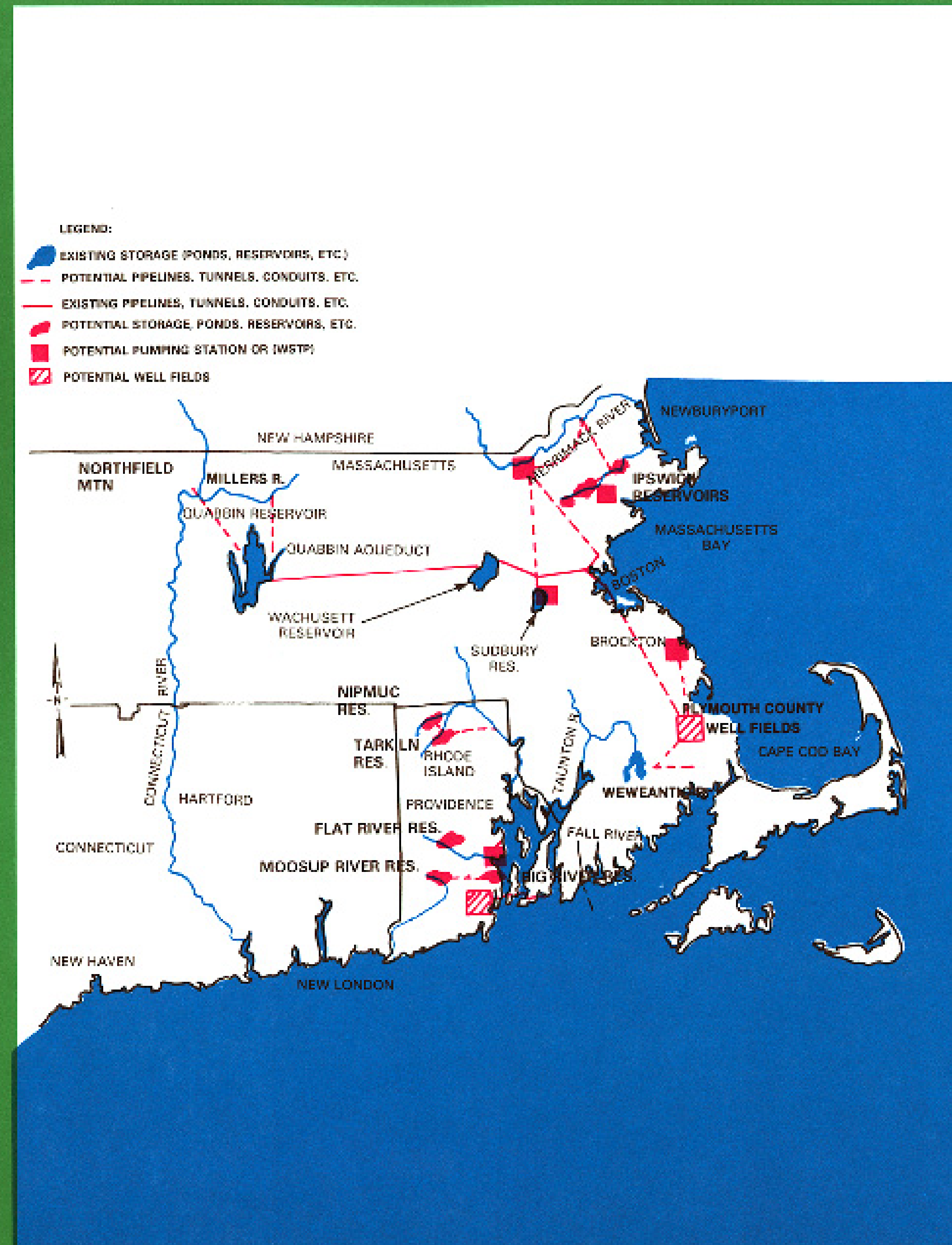


DECISION TREE-BRANCH 3 ALL AMOUNTS IN MGD



*CUMULATIVE ADDITIONAL

BRANCH 3



BRANCH NUMBER THREE—

PROGRAM DESCRIPTION

This branch consists of six projects which combined with local development provide a total yield of 345 mgd for the 1980-1990 decade. The projects are: pumped storage from Northfield Mountain providing 72 mgd; diversions from the Millers River for 76 mgd; diversions from the Ipswich River for storage in offstream reservoirs providing 25 mgd; ground water yielding 12 mgd; diversion from the Weweantic River into existing storage providing 15 mgd; and Big River project yielding 29 mgd. Local developments total 81 mgd in the rural areas of Western Massachusetts, Dukes, Nantucket and Barnstable Counties; and 35 mgd in Eastern Massachusetts.

The 1990-2000 demands would be met by Demand Modification of 30 mgd, redevelopment of the Sudbury River for 35 mgd, development of the Nipmuc and Tarkiln Reservoir projects for 14 mgd and the Flat River Reservoir which would provide 13 mgd. Local development in Eastern Massachusetts would provide 128 mgd, and 15 mgd in Western Massachusetts.

Beyond 2000, development of the Merrimack River or Plymouth County Ground Water would provide 210 mgd, the Moosup River 20 mgd, and Rhode Island ground water 11 mgd. The remainder of the region's needs, 99 mgd, would be met by local development.

PROGRAM RATIONALE

With Northfield Mountain and Millers River projects recommended for authorization by the Corps of Engineers, and with other early time frame projects under active study by local interests, Branch 3 is considered to be the most likely plan. For later time periods, projects were selected from a number of river basins to provide a safeguard against droughts which might not affect all basins with equal severity. Branch 3 is lowest in cost of the three branches and includes several projects in which source areas are close to areas of demand.

PROJECT DATA FOR BRANCH 3

PROJECT	ULTIMATE SAFE YD. MGD	FIRST COST* $ MILLIONS	ANNUAL COST $ MILLIONS INT. & AMORT.	OM & R	THROUGH 1990	THROUGH 2000	THROUGH 2020
BIG RIVER	29	61.55	4.75	1.39	6.14	6.14	6.14
NORTHFIELD (1)	72	55.94	4.09	.91	5.00	5.00	5.00
MILLERS RIVER (1)	76	61.35	4.49	1.28	5.77	5.77	5.77
IPSWICH RIVER	25	65.10	5.03	.18	5.21	5.21	5.21
GROUND WATER	12	29.57	2.28	1.20	3.48	3.48	3.48
WEWEANTIC RIVER	15	38.70	2.99	2.50	5.49	5.49	5.49
N-T RESERVOIR	14	32.64	2.52	.58	0	3.10	3.10
FLAT RIVER	13	11.39	.88	.64	0	1.52	1.52
MERRIMACK	210	542.14	41.87	10.24	0	0	52.11
GROUND WATER R.I.	11	9.64	.74	.50	0	0	1.24
MOOSUP RIVER	20	26.61	2.06	1.22	0	0	3.28
SUDBURY R.	35	52.57	4.06	1.00	0	5.06	5.06
LCD (W)	100	—	—	—	—	—	—
LCD (E)	258	—	—	—	—	—	—
DEM. MOD.	30	—	—	—	—	—	—
TOTAL	920	987.20	75.76	21.64	31.09	40.77	97.40

* ALL FIGURES BASED ON ENGINEERING NEWS RECORD CONSTRUCTION COST INDEX OF 2300

(1) NORTHFIELD AND MILLERS RIVER PROJECTS ARE SHOWN WITH FIRST COSTS UPDATED TO MARCH 1977 PRICE LEVELS AND ANNUAL COST AT THE FEDERAL INTEREST RATE OF 6.375 PERCENT OVER 50 YEARS.

CHAPTER 9: CONCLUSIONS AND RECOMMENDATIONS

FINDINGS AND CONCLUSIONS

Basis for the Study. The genesis of the NEWS Study was the unprecedented drought of the 1960's which caused the people of the northeastern United States to question the previously held assumption that their region had an abundance of water. Droughts had occurred in the past and had caused inconvenience and economic losses. But not until the 1960's, had the great urban centers perceived themselves to be vulnerable to a water system breakdown—a situation involving not inconvenience with severe but acceptable monetary losses, but involving potential loss of life through fire, disease and deprivation along with economic losses of disastrous proportions. The sense of urgency is conveyed in the language of Public Law 89-298 authorizing the NEWS study.

Available Supplies. The study has shown that the Northeast remains, except in the most severe droughts, a region with abundant conventional sources of water supply in virtually all of its parts even with its dense population and high level of economic activity. The study has also shown that the concerns which led to passage of the NEWS Act were well justified even though severe droughts are infrequent events. Many systems are exceeding their safe yields and are approaching conditions of potential shortages even in years of normal supply. While proper management and development of available sources can make it possible to avert severe shortages in the future, the lead time required for accomplishment assures that the three most critical metropolitan areas identified in the study will remain vulnerable to water emergencies for at least the next decade.

The authorizing legislation, in referring to potential facilities for exchanges between river basins, envisaged that interbasin transfers of water might be required. Therefore, early stages of the study examined potential diversions from the Great Lakes, the St. Lawrence River and the Susquehanna River for conveyance over great distances to the major metropolitan centers in the study. The investigations have shown that such large scale diversions are unnecessary for the foreseeable future.

Water Conservation. Although precipitation in most of the Northeast since the 1960's drought has been higher than normal, the occurrence of water shortages in other regions of the United States has increased public awareness of potential shortages in the Northeast. These droughts have also increased public awareness and acceptance of the needs for water conservation which are essential to any long term reduction in water use. The NEWS Study has been sensitive to the potential for reducing demand by conservation measures and has put a significant effort into determining the results which may be obtained. Conservation programs have been included in the estimates of demand and deficits for each critical area given intensive study. Where significant saving could be expected, the adoption of a conservation program, as an item of local cooperation, was made a prerequisite to Federal participation in a water supply project. However, the true effectiveness, in quantity and duration of water savings, from a proposed conservation program is difficult to predict and estimates of projected savings are often matters of controversy. Conservation seems to be a costless, effortless endeavor and it is neither. An effective program must be carefully planned, continuously pursued and enforced by legal sanctions. Responsibility for the program should be at the state and local level since the applicable regulations and ordinances are made at that level. Thus regionally effective plans are institutionally difficult to establish.

The next few years should provide much valuable data on the effectiveness of conservation measures since they are becoming more common throughout the nation. These data may reduce the uncertainty currently attached to estimates of anticipated results. The distinction between conservation programs designed to reduce long range water demands and drought contingency plans, which are temporary and reserved for emergency situations, must be clearly understood. Both are needed and should be a part of any water supply program.

Cost Considerations. Water planners have found that potential new supplies are increasingly expensive even when inflation is discounted. The public, who make comparisons with current water costs provided by facilities built years ago, finds these high costs difficult to accept. However, the closest and most economical sources were developed first and each new supply therefore is more costly to develop.

Emerging Technologies. Certain unconventional sources of supply are likely to become more competitive in price and acceptability with the passage of time and improvements in technology. Direct recycling of treated wastewater will become important in long range planning, perhaps before decisions must be made for projects to meet year 2020 needs. Indirect recycling, already in common use by discharge of treated wastewater into streams and onto land treatment areas, or by direct recharging of aquifers, will increase as technology improves and experience improves confidence in the results. The Potomac

River estuary pilot treatment plant authorized in an interim NEWS report and under construction by Baltimore District in 1977 will contribute to our knowledge of the potential for use of such waters as sources of potable supply.

Desalination was beginning to be competitive in terms of cost in the Northeast until the recent increase in energy costs and could become so again if less costly energy systems become available. Environmental problems such as brine disposal remain to be overcome if the method is to be used in urbanized areas.

Dual water distribution systems which would allow for the use of poor quality water for certain purposes may become feasible where entire new systems are developed. Cost and the disruption required to install a second system make dualization unlikely in established developed areas. These and other similar new or modified technologies may come into use in special circumstances but are considered unlikely to become competitive with conventional sources in the northeastern United States.

Institutional Issues. Early in the study, it was considered likely that Federal involvement in water supply planning might act as a catalyst to the small jurisdictions and encourage the development of regional systems with improved efficiency in providing water services. However, it was found that regionalization generally is not perceived as desirable, except in the largest urban areas where it is a matter of necessity. These institutional barriers make it difficult to arrange for system interconnections, which could increase yields and improve both reliability and flexibility. Combined facilities or management may not be necessary but a regional approach to the analysis of water problems is essential to reach an equitable distribution of resources and to achieve reasonable compromises between source and demand areas.

The institutional difficulties are exemplified by the relations between New York City and the areas to which it has reached out in the past for water. The example is particularly pertinent to the NEWS Study because the proposed Hudson River Project constitutes another withdrawal from outside the immediate area. In this instance, however, State and local cooperating officials from the City and surrounding counties are discussing the necessary institutional arrangements, to include the possibility that the city system become part of a regional system from which the upstate counties will also be supplied.

Development Trends. Forecasts of the future have always been subject to differences of opinion. However, future trends in growth in the urban centers of the Northeast have an unusually high degree of uncertainty at the present time. Some believe that the population has peaked and is on the decline in the metropolitan areas as well as in the central cities.

The projection problem is made more difficult by differences of opinion as to what the growth objectives should be. While the disadvantages of high density in residential, commercial and industrial development are recognized, and deplored; the losses in income, contraction in services and reduced community well-being which accompany low growth are also recognized and the result is an ambivalence toward development of the resource base including the water supply component. An adequate supply of water is not a sufficient condition to insure economic growth but it remains a necessary condition. Water has been one of the Northeast's competitive advantages and it is one that cannot be neglected if a resurgence is to occur.

In each of the three critical areas, additional reservoirs are indicated as potential sources of increased yield for the long range plans of 2020 and later. At present, such additional reservoirs are not favored by state and local interests. Their inclusion as potential elements in future plans does not constitute an endorsement of the projects but rather recognition that these impoundments are potential sources. Such additional surface water could be developed in such major basins as the Potomac River in the Washington Metropolitan Area, the Hudson River Basin in the New York Metropolitan Area and the Connecticut and Merrimack Rivers of Eastern Massachusetts - Rhode Island.

Environmental Considerations. In general, the impacts of severe and widespread water shortages are more serious than the adverse environmental effects of source development. The real differences of view center on the likelihood of a severe water shortage and the magnitude of the environmental impacts.

Environmentally oriented groups encountered in the study have generally shown that the vital importance of water supply is recognized and have given primary attention to the questions of (a) whether, after a meaningful effort at water conservation, a given region will need additional supplies; (b) whether projected increases in future demand are consistent with current data; (c) whether the least environmentally damaging alternatives have been identified; and (d) whether sufficient data is available to determine the environmental consequences of a considered project. Some of the objections are based on purely philosophical, "anti-development" grounds. There has also been evident public concern that environmental issues not prevent needed projects, when the impacts are highly speculative or less significant than the benefits foregone if the project does not proceed. The environmental review procedure and the environmental inputs continue to foster a more vigorous search for alternatives and a more rigorous examination of projects proposed.

Planning in the Critical Areas. The Washington Metropolitan Area, because it is so heavily dependent upon run-of-the-river discharges and is so deficient in backup storage, is most vulnerable to short term as well as long term shortages. In systems with large amounts of storage, there is more time to perceive developing shortages and enact contingency measures. Funds have been appropriated for the Potomac estuary emergency water pumping station of the Washington Aqueduct Division, scheduled to be initiated in 1977 and completed in 1978. This will be a useful but strictly emergency facility. The estuary pilot plant under construction in 1977 may demonstrate that the estuary can be used to a greater extent. Completion of the Bloomington Project in 1980 or 1981 will increase the safe yield of the Potomac by about 30 percent. Verona and Sixes Bridge projects would similarly contribute if they were to proceed to construction, but this appears unlikely at this time because of lack of support. Baltimore District continues to seek acceptable solutions in its Metropolitan Washington Water Supply Study. The long lead time between a decision and project implementation means the Washington Metropolitan Area will remain vulnerable to water crises for many years to come.

The Corps of Engineers has no region-wide water supply studies in progress for Eastern Massachusetts-Rhode Island but two projects have been recommended for authorization by the Corps-Northfield Mountain and Millers River projects. With the Metropolitan District Commission's Quabbin Reservoir, the region is less vulnerable to short-term periods of shortage than is the Washington Metropolitan Area, but the two additional projects should be built if the region is to avert critical supply situations.

No NEWS projects have been previously authorized or proposed for authorization in the New York Metropolitan Area. The states of New Jersey and Connecticut have concluded that they will be able to meet their near term water needs until about the year 2020. New York State, however, agrees with Corps estimates that southeastern New York has a current deficit which will reach about 400 mgd by the year 2000 and has expressed agreement with a NEWS finding that a project to augment the New York City system by intermittent withdrawals from the Hudson River is the most feasible way to obtain the needed supply.

Hudson River Project. The project is described in the Appendix to this report. In brief, the project would take water from the Hudson River about 80 miles above the Battery in New York City at a maximum rate of 950 mgd to produce an annual increment of 390 mgd in the system safe yield. The water would be pumped to a filtration plant, treated and then conveyed by a deep tunnel to Kensico Reservoir in the New York City system in Westchester County. Conveyance to demand centers in New York City would be accomplished by completion of Stage 1 and construction of Stages 2 and 3 of City Tunnel No. 3 as part of the Federal project. A pipeline to Nassau County would complete the plan.

First cost of the project is estimated to be $3.70 billion. Annual charges would be $346 million. The benefit-cost ratio is 1.3. The project will be designed and constructed by the United States and conveyed for operation, maintenance and any future reconstruction to a duly authorized public body who would repay to the United States the cost of construction. In addition, the local interests will enact a water conservation program and an environmental monitoring program to assure that the project is operated so that severe environmental effects do not occur. The Governor of the State of New York has provided assurances that the conditions of local cooperation will be met.

Because of the magnitude of the investment and the degree of uncertainty resulting from lack of sufficient data to determine completely project impacts on the complex estuarine ecosystem, cooperating local governments, public and private groups have expressed reservations about the project, or have expressed opposition to it. There have also been concerns that the projected water demand in the region may be too high because of a loss of population and increased water conservation. However, there has been no agreement on a better means of augmenting the regional supply.

Questions still needing resolution are beyond the survey study scope in terms of expense and time required. These issues can best be resolved in a Phase I General Design Memorandum (GDM) which would include a review of formulation, geology and borings, aquatic and terrestial environmental inventories, pilot intake operation, pilot treatment plant operation, review of environmental impacts, review of City Tunnel No. 3, further design and cost estimates, preparation of report, coordination and public participation. It is estimated that the Phase I GDM can be completed in 3 to 5 years at a cost of $8 million.

RECOMMENDATION

I recommend the selected plan for the Hudson River Project described in the Appendix to this *Summary Report* be authorized for the Phase I General Design Memorandum stage of advanced engineering and design at an estimated cost of $8,000,000.

James L. Kelly

JAMES L. KELLY
Major General, USA
Division Engineer

ANNOTATED LIST OF NEWS REPORTS

I OVERALL STUDIES

1. *Plan of Study for Northeastern United States Water Supply,* Corps of Engineers, North Atlantic Division, September 1966. A general overview of the NEWS Study is presented, including a background discussion of the area, short and long range objectives, and a discussion of the relation between the NEWS Study and similar activities of the States and other Federal Agencies.
2. *1966 Water Drought Restrictions,* Public Service Research, 1967. Presents an inventory of the water use restrictions which were placed in effect during the 1966 drought.
3. *Water Utility Lists, Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Washington, D.C., Pennsylvania, Rhode Island, Vermont, Virginia, West Virginia,* Public Service Research, 1967. Basic data is provided on all water supply companies in the NEWS Area, including population served, quantity produced, and gross water revenue.
4. *Water Utility Directory,* Public Service Research, September, 1968. The directory lists by state all water utilities including county location, size, classification, source of water, and nature of ownership.
5. *Municipal Financing of Water Projects for Northern New Jersey,* Sanford L. Bordman, January, 1969. Case study of the financial aspects of investments for water supply systems for the municipalities of Northern New Jersey.
6. *Anticipated and Emerging Advances in Water Supply Technology,* International Research & Technology Corporation, February, 1972. Studies anticipated and emerging major advances in water supply technology, including advanced water treatment of polluted, brackish and otherwise unusable sources, desalination, weather modification and iceberg harvesting.
7. *Preliminary Study of Long Range Water Supply Problems of Selected Urban Metropolitan Areas,* Anderson-Nichols & Co., Inc., November, 1973. Examines 26 urban metropolitan areas throughout the Northeast and identifies the areas which may experience major regional municipal, domestic and industrial water supply problems. The report also investigates opportunities to provide these areas with adequate water supply through the year 2020. Volume I Main Report. Volume II Area Reports.
8. *Northeastern United States Water Supply Study, Interim Report, Critical Choices for Critical Years,* U.S. Army Corps of Engineers, November 1975. Provides a brief overview of the demand for water in the northeastern portion of the U.S., and puts forward the various general means for meeting these demands. A chapter is devoted to each of the three most critical areas, the Washington Metropolitan Area, the New York Metropolitan Area, and the Eastern Massachusetts, Rhode Island Metropolitan Area, displaying in detail the needs and major alternative sources of water available for satisfying these needs. Water supply projects are arranged in alternative programs which meet the needs through the year 2020 in each area. These alternative programs demonstrate the critical choices which must be made at the earliest possible date in each area.

II WASHINGTON METROPOLITAN STUDY AREA (WMA)

1. *Potomac Estuary Water Supply:* The Consideration of Viruses, Environmental Protection Agency, March 1973. This study provides the results of laboratory experiments on the differences in resistance to chlorination of twenty-five strains of human intestinal viruses that were suspended in estuary water. Conclusions are drawn from this work from a public health viewpoint as to the feasibility of using the Potomac Estuary as a supplemental source of water for the Washington Metropolitan Area. This was a companion study to the " Potomac Estuary Water Supply: Its Feasibility as a Supplementary Source."
2. *Potomac River Basin Water Supply, An Interim Report,* Corps of Engineers, North Atlantic Division, Baltimore District, April, 1973. This Report is a response to the 1972 Conference Report on S.4018, "Public Works on Rivers and Harbors", to reformulate the Sixes Bridge and Verona Dam and Lake projects for purposes other than low flow augmentation for water quality. The Report evaluates water supply problems in the Potomac River Basin with special emphasis on the Washington Metropolitan Area. It integrates the two Projects into an overall long-term water supply program for the WMA, recommends that a prototype advance water treatment plant be Federally authorized and constructed, and thus served as an interim report on the ongoing studies in the WMA under the Northeastern United States Water Supply Study (Title I, PL 89-298). Summary & Volumes I, & II.
3. *Metropolitan Washington Area-Special Water Supply Study,* Tetra Tech, Inc., July, 1973. This study provided services and work elements necessary to determine the impact

of non-point pollution on water supplies; to review, evaluate, and update information on present water resources and supply systems in the WMA; and to prepare a base-line environmental analysis of the study area with specific emphasis on water supply. This effort was limited to collection, review and interpretation of the existing information.

4. *Potomac Estuary Water Supply: Its Feasibility as a Supplemental Source,* Hydroscience, Inc., August, 1973. This study examines the potential for meeting drinking water standards with Potomac Estuary water treated by known techniques. The study employed a steady-state water quality model of the estuary to determine what the quality of treated estuary water would be under various conditions of river flow and water demand.

5. *Potomac Estuary Water Supply: Architectural and Urban Design Considerations,* Paul D. Spreiregen, August, 1973. This report is a graphical essay in site layout and architectural design criteria for the proposed one mgd pilot estuary water treatment facility.

6. *Growth and Water Supply in the Washington SMSA,* Development Sciences Inc., January, 1974. This report analyzes the magnitude and distribution of population growth and its relationship to water supply in the WMA. The study first examines how well-water supply devices alone could aid in the control of population growth, and second it takes a broader look at the problem of growth control by taking an inventory and examining all growth control mechanisms then being studied by each county in the Washington Standard Metropolitan Statistical Area (SMSA).

7. *Preliminary Institutional Arrangements for Water Supply in the Washington Area,* Development Sciences, Inc., January, 1974. This report presents the existing institutional setting of the Metropolitan Washington area. The report delineates the institutional, legal and funding problems that would be faced during implementation of alternative water supply programs studies by the WMA Study group. Suggestions are made on how the alternative programs could be modified to make them politically feasible.

8. *Environmental Assessment for the Construction and Operation of a 1 mgd Prototype Water Treatment Plant,* Hydroscience, Inc., August, 1974. This document describes the ways in which the Prototype Water Treatment Plant would affect the environment, and is issued pursuant to the National Environmental Policy Act of 1969 (PL 91-190).

9. *Potomac Estuary Water Supply: A Prototype Water Treatment Facility,* Hydroscience, Inc., December, 1974. This report was the basis of a Corps proposal to construct and operate a one mgd pilot estuary water treatment facility (now authorized). Based on the results of operating a time-variable water quality model, it was concluded that the Potomac Estuary appears to be suitable as a permanent regional source of water, but due to potential health hazards, extensive testing would be required. Operation of the proposed prototype facility would provide the detailed information needed to evaluate this approach to water supply. The report also presents a design for the pilot facility and site selection criteria for both a pilot and regional facility.

10. *Simulation Model for the Metropolitan Washington Area Water Supply System,* Vol I & II, Meta Systems, Inc., April 1975. A model was developed to allow the examination of the interconnected aspects of the WMA Water Supply system and the possibility of using various combinations of devices and operating procedures to meet both short and long term water supply requirements. The model is descriptive rather than predictive in that it describes the consequences of decisions made rather than indicating what decision is to be made. The model was structured to develop a system configuration which satisfies demands for the multiple demand centers of the system.

11. *Environmental Impact of Alternative Water Supply Programs and Projects for the Washington Metropolitan Area,* WAPORA, Inc., September, 1975. Provides environmental data and projected impact assessments of alternative water supply projects and programs for the WMA. Using data collected these water management projects and programs are compared and impacts are assessed on geographic units ranging from the regional to the immediate project area.

12. *Washington Metropolitan Area Water Supply Study Report,* Corps of Engineers, North Atlantic Division, November, 1975. Provides a complete and comprehensive analysis of feasible alternative solutions to the Washington Metropolitan Area water supply problem; describes the range of alternatives possible; provides the necessary information for agreement on a first step for a survey of a particular project. Consists of Main Report and 4 Annexes.

13. *Annex A, Open Planning and Coordination,* November, 1975. Contains a description of how open planning took place in the WMA and identifies the publics which were involved in open planning. Also documents comments and views offered by various publics during the study, and identifies the points where public feedback is either incorporated

or responded to in the process of formulation of alternative water supply programs. In addition a 'Staff Report on the Alternative Water Supply Programs for the Metropolitan Washington Area" has been included. This report incorporates the issues and views of the Washington Community during the early stages of plan formulation and evaluation, discusses these views mainly with respect to program formulation criteria and types of techniques to use to solve the water supply problem, and presents preliminary programs to satisfy objectives and criteria derived from Community involvement.

14. *Annex B, Water Supply, Demand and Deficits,* November, 1975. Describes in detail the assumptions and procedures dealing with the interrelationship between the water supply and demand situation in the WMA.
15. *Annex C, Engineering Feasibility of Alternative Water Supply Projects,* November, 1975. Describes the various water supply projects investigated in the WMA Water Supply Study, and describes and analyzes the NEWS programs in terms of the ability of component projects to meet the various program objectives.
16. *Annex D, Effects of Water Supply Deficits and Socioeconomic Impact Study of Alternative Water Supply Programs,* (2 Vols.), November, 1975. Defines and assesses the socioeconomic, physical, aesthetic, and other miscellaneous short-term effects of water supply deficits in the Metropolitan Washington Area.

III NEW YORK METROPOLITAN STUDY AREA (NYMA)

1. *Surface Water Supply Capabilities of Northern New Jersey River Basins,* Quirk Lawler and Matusky Engineers, December, 1968. The objective of this study was to obtain firm yields, for various drought occurrences, of the surface water supply systems within the Passaic, Hackensack, Raritan, Navesink, and Shark River Basins.
2. *Engineering Feasibility Report on Alternative Regional Water Supply Plans for the Northern New Jersey-New York City-Western Connecticut Metropolitan Area,* Metcalf & Eddy-Hazen & Sawyer, November, 1971. This investigation was performed to develop feasible engineering alternatives for water supply systems to meet the domestic and industrial water needs of the study area to the year 2020.
3. *Organizational, Legal, and Public Finance Aspects of Regional Water Supply,* Institute of Public Administration, July, 1972. This report investigated the legal, institutional and economic issues involved in regional ization of public water supply in the New York and southeast New England NEWS Study area, and presented alternative general institutional frameworks for regional water supply management. Volumes I, II & III.
4. *Effect on the Environment of Regional Water Supply Alternatives for the Northern New Jersey-New York City-Western Connecticut Metropolitan Area,* The Center for the Environment and Man, Inc., November, 1972. This report contains an overview and preliminary analysis of probable environmental impacts for the fourteen projects used to develop the seven regional programs described in the Engineering Feasibility Report (November 1971) assuming maximum development of facilities for water supply (which would not necessarily be the case). The report describes qualitative rather than quantitative impacts and does not attempt to rank projects by their impacts.
5. *Evaluation of Alternative NEWS Water Supply Systems for the Northern New Jersey-New York City-Western Connecticut Metropolitan Area,* Linton, Mields and Coston, Inc., June, 1973. The purpose of this study was to develop an impact assessment and multi-objective evaluation framework, with the attendant plan formulation process, and to apply this framework on the local case study and regional levels to the seven illustrative regional programs for the New York Study Area developed in the Engineering Feasibility Report, November 1971. Three Volumes.
6. *Further Development of Regional Water Supply Development Alternatives for Northern New Jersey-New York City-Western Connecticut Metropolitan Area,* Parsons, Brinckerhoff, Quade and Douglas, Inc., June, 1973. The objective of this study was to develop additional project alternatives and illustrative regional programs for water supply work in the New York Metropolitan Study Area, supplementary to the work in the Engineering Feasibility Report, November 1971, and to prepare a computer programming algorithm to serve as a tool for analysis of additional regional programs by the contracting agency.
7. *Legal, Institutional and Cost-Sharing Requirements for Implementing Water Supply Projects in the Northern New Jersey-New York City-Western Connecticut Metropolitan Area,* Booz Allen Public Administration Services, Inc., June, 1973. The purpose of this study was to further examine the legal, institutional, and cost-sharing requirements for the implementation of both individual projects and regional programs of projects for water supply in the New York Study Area.

8. *Water Supply: Wastewater Management Aspects for the Northern New Jersey-New York City-Western Connecticut Metropolitan Area,* Nebolsine, Toth, McPhee, Associates, June, 1973. The objective of this study was to perform a survey of the existing legislation, programs, water quality and future quality conditions of water sources in the study area and the Delaware, Hudson and Housatonic River Basins, and to examine programs to protect or enhance quality of alternative water supply sources which may be utilized to meet the projected needs of the New York Metropolitan Study Area. This work was developed at a low level of detail, utilizing existing data.

9. *An Opportunity for the Future: Integrated Water Supply-Power Generation-Wastewater Management-Land Control,* Quirk, Lawler and Matusky Engineers, December, 1973. The objective of this study was to evaluate the feasibility of implementing a wastewater-total resource management program for Long Island, New York, which would eventually combine a nuclear power plant, a waste treatment facility and a land application system and/or other methods of waste heat utilization for the overall purpose of system efficiency and improvement of water supply management on Long Island.

10. *Institutional Issues Surrounding a Hudson River Diversion to New Jersey,* Dunka, Gaston and Westwater, Inc., August, 1974. This report discusses the legal, institutional and financial problems likely to occur if Hudson River water from New York State is diverted to New Jersey as part of a regional water supply program.

11. *Hudson River Hydrology Study,* Quirk, Lawler and Matusky Engineers, August, 1974. An analysis of the firm yields available for water supply in the Hyde Park -West Park area for several alternative operating schemes of existing and considered reservoirs in the Hudson River Basin. A Summary, the Report and Appendices A, B, and C in three volumes.

12. *Hydraulic Analysis of the New York City Water Supply System,* Quirk, Lawler and Matusky Engineers, September, 1974. The study provides an analysis of the delivery portions of the City's water supply system from the sources to the head of the local distribution system.

13. *Interconnections Study,* Quirk, Lawler & Matusky, September, 1974. Utilizing the alternatives presented in the "Joint Venture Report" for providing water to the Metropolitan area in each of the time frames 1980, 2000 and 2020, this report develops several systems by which water could be distributed from the mode of entry into the area and to the individual water utilities.

14. *Report on the Interconnection and Safe Yields of the Major Water Utilities in Northern New Jersey,* Dr. Robert M. Hordon, Consultant, September, 1974. This study provides an inventory of all interconnections that exist for the eleven major water utilities in northern New Jersey. The report also examines the safe yields and annual average diversions for each utility.

15. *Water Demand Projections and Sensitivity Analysis for the New York Metropolitan Area,* INTASA, Inc., September, 1974. This report describes the methodology used to develop projections of future water demand for the NYMA. The report also analyzes the sensitivity of these projections to be altered assumptions about underlying conditions, such as population, economic activity, land use and community development, and basic water consumption practices.

16. *Analysis of Regional Water Supply Programs for the Northern New Jersey-New York City-Western Connecticut Metropolitan Area,* Linton & Co., June, 1975. This study further develops, extends and applies the analytical techniques for impact assessment and multi-objective evaluation orginally developed in Evaluation of Alternative NEWS Water Supply Systems. Greater emphasis is placed on analysis of environmental, social and institutional impacts than in the earlier study, and assessment is made of short-run construction impacts, system reliability, and system flexibility. The expanded methodologies are applied to selected projects and programs. (4 Volumes)

17. *An Opportunity for the Future: Integrated Water Supply-Power Generation-Wastewater Management-Land Use Control,* Quirk, Lawler, and Matusky Engineers, December 1973. This study presented the concept of integrating water supply needs with power plant cooling needs and wastewater management needs. The emphasis was on heat transfer to wastewater effluent for the purpose of effluent renovation and land disposal of the effluent for ground water recharge.

18. *Master Plan for a Demonstration of Integration of Water Supply-Power Generation-Wastewater Management-Land Use Control,* Quirk, Lawler and Matusky Engineers, October 1975. This is a survey-scope study for a demonstration project to develop operating experience and resolve technical uncertainties in total resource management. This effort, an extension of the study *An Opportunity for the Future: Integrated Water Supply-Power Generation-Wastewater Manage-*

ment-Land Use Control, was conducted jointly by NYMA Study and the New York State Atomic and Space Development Authority. Other Federal, State and local agencies have also contributed to the planning and design of the project.

19. *Preliminary Analysis of Hudson River High-Flow Skimming Project and Framework for Environmental Analysis,* Metcalf and Eddy of New York, Inc., December 1975. This study examines the feasibility of several sites for intake and treatment plant facilities and provides an approach for evaluation of environmental impacts on the estuary. Indicator species are used and descriptions of each are provided.
20. *Water Conservation Measures for the New York Metropolitan Area,* NEWS Study staff, January 1976. This report analyzes the reduction in publicly-supplied water demand potentially achieveable in the New York Metropolitan Area by means of conservation, including universal metering, control of distribution system leakage, pricing, industrial recirculation, domestic conservation devices, public education, and temporary contingency measures for a drought emergency. Implementation programs for each are described and costed where such information is available. (Appendix Part II Section E)

IV EASTERN MASSACHUSETTS-RHODE ISLAND METROPOLITAN AREA I-WATER SUPPLY REPORTS:

1. INTERIM MEMORANDA These eight limited detailed studies were intended to present an overview of the water supply situation for some of the larger metropolitan areas within New England.

   No. 1—New Bedford, Fall River and Taunton, Corps of Engineers, New England Division, April, 1968. This Tri-City area in southeastern Massachusetts was analyzed to evaluate its future water supply outlook. The population, water supply and water demand were discussed and projections made for the population and water demand through the year 2020. Possible sources of water adequate for a regional supply were examined and discussed.

   No. 2—Springfield, Chicopee, Holyoke Area, Corps of Engineers, New England Division, April, 1968. The Springfield-Chicopee-Holyoke region in western Massachusetts was examined for its capability to meet future water supplies. Present and future population and water demand figures through the year 2020 were presented. Adequacy of the region's three major systems was investigated and apparent urgent and future needs were discussed and possible courses of action were described.

   No. 3 – Bridgeport-New Haven subregion, Corps of Engineers, New England Division, July, 1968. The Bridgeport-New Haven, Connecticut area was investigated to determine future potential water supply deficits. Present and future population and water demand requirements were presented through the year 2020. Adequacy of the major water systems was studied and apparent urgent and future needs were discussed. Potential regionwide supply sources were examined and described.

   No. 4 – Southern New Hampshire Tri-City area, Corps of Engineers, New England Division, August, 1968. The Concord-Manchester-Nashua area of New Hampshire was investigated to determine future water supply needs. Present and future population and water demands through the year 2020 were presented. Sources of water which could be developed to meet the needs through 2020 were examined and described.

   No. 5 – Worcester-Boston, Corps of Engineers, New England Division, September, 1968. The Metropolitan District Commission (MDC) system, the major supplier in the Worcester-Boston area, was investigated in this memo considering only the then existing system service area. The present and projected population and water demands through the year 2020 and the capability of the system to meet these needs was described.

   No. 6—Metropolitan Boston Area, Corps of Engineers, New England Division, September, 1968. This memorandum builds on Memo No. 5 in that it examined the implications of the addition of future suburban customers to the MDC system.

   No. 7 – Worcester-Boston, Corps of Engineers, New England Division, September, 1968. Five sub-regions within the Worcester-Boston region but not included in the primary service area of the MDC were discussed in this report. These sub-regions—City of Fitchburg, City of Worcester, Ipswich River Watershed District, Upper Charles River Basin Communities, and the Central Plymouth County Water District—were examined for their capability in meeting future water demands through the year 2020.

   No. 8 – Rhode Island, Corps of Engineers, New England Division, October, 1968. Future water supply needs within the State of Rhode Island were examined. Present and future population and water demand figures through the year 2020 were presented and possible supply sources were described.

2. *St. Lawrence River Diversion,* Corps of Engineers, New England Division, October, 1968. This report studied the potential of utilizing the St. Lawrence River as the source for meeting the future water supply requirements of the Northeastern United States as projected through the year 2020. Two plans and preliminary cost estimates for conveying water supply to major users are included in the report. The study indicates general scope of the engineering and economic feasibility of this diversion.

3. *Draft—Feasibility Report on Alternative Regional Water Supply Plans for Southeastern New England,* Corps of Engineers, New England Division, November, 1969. The objective of this report was to formulate engineering alternatives for a regional water supply system to meet future needs within southeastern New England. As described in the report, these engineering alternatives were formulated without regard to the "institutional restraints—legal, economic, or organizational—which might inhibit regionalization of water supply." (Main Report and Appendix)

4. *Ecological Study Merrimack River Estuary—Massachusetts,* Normandeau Associates, Inc., November, 1971. This study was designed to determine the potential environmental effects of diversion of water from the Merrimack River in the vicinity of Lowell, Massachusetts, and to give a qualitative evaluation of the significance of these effects on the ecology of the estuary and associated wetlands.

5. *Possible Effects of Various Diversions from the Connecticut River,* Essex Marine Laboratory, May, 1972. This study reports on efforts to predict the probable impact of upstream freshwater diversion during freshet periods on the salinity-temperature regimen of the Connecticut River estuary and to further correlate these changes with possible effects on the biotic community of the estuary.

6. *Identification and Assessment of Socio-Economic Impacts on the Connecticut and Millers River Basin Diversions,* Abt Associates, Inc., June, 1972. This report describes investigations which identify changes attendant on the Northfield Mountain and Millers River Basin water Supply projects that will affect human population in the immediate supply area and among potential receivers. Changes are quantified and characterized where possible in terms of magnitude, direction and duration. (Volumes I and II)

7. *Water Quality Studies, Connecticut and Millers River Systems and Quabbin and Wachusett Reservoirs, Massachusetts,* New England Research, Inc., June, 1972. This report describes studies on the probable effects of diversion of flow from the Connecticut and Millers River Basins and their possible effects on the Quabbin and Wachusett Reservoirs.

8. *Site Preservation for Water Resources Projects, A Legal, Economic and Institutional Analysis,* Curran Associates, Inc., January, 1973. This study examined methods historically employed to assure tracts of land will be available for future water resources development; the success of these methods and an evaluation of each of these methods as they pertain to New England. Efforts by the State of Rhode Island in acquiring reservoir site preservation are used as a case study by the report.

9. *Millers River Basin Water Supply Project,* Corps of Engineers, New England Division, October, 1974. This study reports investigations into methods of augmenting water supply sources for a number of communities in the eastern Massachusetts region. Population and water demand figures both present and projected are discussed and alternative methods of meeting future supply means are described. The report recommended development of water resources in the Millers River Basin via facilities which would divert high flows from the Millers Basin to Quabbin Reservoir. (Volumes 1 through 4).

10. *Northfield Mountain Water Supply Project,* Corps of Engineers, New England Division, October, 1974. This study which is a companion of the Millers River Basin project report recommended the development of a high flow skimming operation which utilizes the existing pumped storage hydroelectric facility at Northfield Mountain and diverts flow to Quabbin Reservoir. (Volumes 1 through 3).

11. *Environmental (Impact) Statements — Northfield Mountain, Millers River Diversion,* Corps of Enginers, New England Division, December 1973.

12. *Water Demand Study, Eastern Massachusetts Region,* Coffin and Richardson, Inc., November, 1974. This study investigated existing patterns of municipal water use for domestic, commercial, industrial, municipal uses and distribution losses. The potential for modifying the recent past trend of increasing water consumption by water use conservation education programs, pricing policies, use of water-saving appliances, institutional restrictions and leak detection and maintenance programs were examined and discussed.

13. *Water Treatment Plant Study, Merrimack River, Massachusetts,* Hayden, Harding and Buchanan, Inc., March, 1975. This study de-

termined necessary water treatment plant unit processes required to deliver a high quality drinking water supply utilizing the Merrimack River as a source. Construction and operating costs for various sized plants were developed and displayed.

14. *An Investigation of Some Environmental Impacts for Possible Diversions of Flow from the Merrimack River,* Jason M. Cortell & Assoc. Inc., April 1975. This Study demonstrates that substantial diversions are possible from the Merrimack River without compromising proposed anadromous fish restoration programs. It specifies minimum flows in the River for each month of the year. When natural flows (or remaining flows) are below these quantities, water should not be diverted.

15. *Merrimack River Basin Water Supply Study,* Corps of Engineers, New England Division, January, 1977. Investigates the water supply needs of communities within the Massachusetts portion of the Merrimack River Basin, and evaluates the potential which the Merrimack River and other alternatives may have as a long range source of water supply for the eastern Massachusetts region. The report also investigates the possibility of servicing portions of southeastern New Hampshire from the Massachusetts portion of the River.

IV. EMRI (2-WASTEWATER REPORTS)
(A) BOSTON HARBOR

1. Forum, Water Quality of Boston Harbor-Massachusetts, Proceedings November 30-December 1, 1972, Corps of Engineers, New England Division

2. *Plan of Study, Boston Harbor, Eastern Massachusetts Metropolitan Area,* Corps of Engineers, Commonwealth of Massachusetts & MDC, May, 1973.

3. *Environmental Conditions in the Eastern Massachusetts Metropolitan Area and Probable Impacts of Wastewater Management Alternatives,* Normandeau Assoc., February, 1975.

4. *EMMA Study,* Metcalf & Eddy, Inc., March, 1976. This intensive inter-agency study addresses methods for combatting pollution in the Boston Harbor—Eastern Massachusetts Metropolitan Area (EMMA). Consists of a Main Report, a Summary Report and the following 15 Technical Data. Appendices in 22 volumes.

   Technical Data Volume 1, Planning Criteria, Metcalf & Eddy, Inc. October 1975. Covers the development of planning data for projecting sewerage needs in the EMMA area. Projections of population, employment, and land use for 1990, 2000, 2020 and 2050 for each community are made.

   Technical Data Volume 2, Engineering Criteria, Metcalf & Eddy, Inc. October, 1975. Covers the engineering criteria used in the project including the bases of estimating wastewater flows, sewerage needs and costs. Projections of sewerage needs and wastewater flows are made for each community.

   Technical Data Volume 3, Industrial Process Wastewater - Analysis and Regulation, Metcalf & Eddy, Inc., October, 1975. Develops and presents the formulation of updated rules and regulations for industrial wastes discharged to the Boston Metropolitan District Sewerage system which will conform to current Federal and State requirements.

   Technical Data Volume 3A, Study of Certain Industrial Wastes, Jason Cortell, October, 1975. This volume reports on the identification and location of 27 types of industries. For each industry identified, the volume and constituents of the process wastes discharged are reported.

   Technical Data Volume 3B, Study of Wastes from Large Industries, Jason Cortell, October, 1975. This volume reports on the identification and location of industries discharging 50,000 gallons per day or more of process wastes. For each industry located, the volume and characteristics of the discharged waste are reported.

   Technical Data Volume 4, Water Oriented Waste Water Utilization Concepts, Metcalf & Eddy, Inc., October, 1975. Study of anticipated wastewater management problems in 109 communities of the EMMA, in connection with expanding and upgrading the Nut and Deer Island primary sewage treatment plants.

   Technical Data Volume 5, Land Oriented Wastewater Utilization Concept, Woodman and Howard, October, 1975. Reports on the formulation and design of a land application wastewater treatment system for the Eastern Massachusetts Metropolitan Area.

   Technical Data Volume 6, Formulation of Wastewater Utilization Plan, Metcalf & Eddy, Inc., October 1975. Covers the deliberative process that was followed between the Development of Concepts 1 through 4 (in Volume 4), Concept 5 (in Volume 5), and the adoption of the Recommended Plan as presented in Vol. 15.

   Technical Data Volume 7, Combined Sewer Overflow Regulation, Metcalf & Eddy, Inc., Nov., 1975. Presents an evaluation of the combined sewer overflow problem in the Boston Harbor area in terms of quantifying the problem and identifying the direction that technical environmental and economic analyses should take.

Technical Data Volume 8, Urban Stormwater Management, Corps of Engineers, New England Division, October, 1975. Reports on the quantity and quality of urban stormwater runoff in the Eastern Massachusetts Metropolitan Area. Also included is an array of alternatives for managing the stormwater together with costs and a projection of effects on the receiving items.

Technical Data Volume 8A, Appendix to Urban Stormwater Management, Corps of Engineers, New England Division, October, 1975. Appendix to Vol. 8.

Technical Data Volume 9, MDC Interceptor and Pumping Station Analysis and Improvement, Metcalf & Eddy, Inc. 1 October, 1975. Presents the inventory and evaluation of the MDC interceptors, pumping stations and headworks in terms of their adequacy to meet projected needs under various concepts and the recommended plan, and recommends the general upgrading required at the pumping stations and headworks.

Technical Data Volume 10, Deer Island Wastewater Treatment Plant Analysis and Improvements, Metcalf & Eddy, Inc., October, 1975. Covers the basic design criteria for upgrading the existing primary plant and providing those facilities that would be required to accomplish secondary treatment including flows and costs.

Technical Data Volume 11, Nut Island Wastewater Treatment Plant Analysis and Improvements, Metcalf & Eddy, Inc., October, 1975. Covers the study performed to analyze the necessary improvements to the primary treatment facilities at the Plant, together with the work necessary to provide secondary treatment capabilities at the facility.

Technical Data Volume 12, Parts I & II, Financing and Management, Peat, Marwick, Mitchell & Co., October, 1975. Contains the findings of the management phase of the EMMA study, the objectives of which were to evaluate and recommend modification to the organizational entity and financial mechanisms required to manage, administer, control, fund and operate the recommended system.

Technical Data Volume 13, Impact Analysis and Evaluation, Corps of Engineers, New England Division, October, 1975. Summarizes the identified impacts of wastewater management as discussed in Volumes 13A-13D and provides the evaluation required by Principles and Standards.

Technical Data Volume 13A, Biological Impact Analysis, Normandeau Associates, Inc., October, 1975. Reports the identified impacts of wastewater management concepts in the Eastern Massachusetts Metropolitan Area with particular emphasis on aquatic biological impacts.

Technical Data Volume 13B, Socio-Economic Impact Analysis, ABT Associates, October, 1975. Reports on the identification and analysis of impacts to the socio-economic environment of Eastern Massachusetts, resulting from wastewater management concepts.

Technical Data Volume 13C, Hygienic Impact Analysis, Corps of Engineers, New England Divison, October, 1975. Discusses the effects on the public health of various wastewater management concepts.

Technical Data Volume 13D, Visual, Cultural and Design Impact Analysis, Woodman and Howard, October, 1975. Reports the effects of regional wastewater management concepts upon the visual-cultural environment and reports on the design implications of various facilities.

Technical Data Volume 14, Public Involvement, Corps of Engineers, New England Division, October, 1975. Reports on the Open Planning activities and results in the Boston Harbor-Eastern Massachusetts Metropolitan Area Wastewater Management Study.

Technical Data Vol. 15, Recommended Plan and Implementation Program, Metcalf & Eddy, October, 1975. Covers the recommendations made as a result of the EMMA Study.

IV 2 (B) MERRIMACK RIVER

1. *The Merrimack: Designs for a Clean River,* Corps of Engineers, North Atlantic Division, September, 1971. General feasibility study investigating comprehensive wastewater management to make presently polluted waters available for water supply. This Study entails a pilot wastewater study of the Merrimack River Basin. (Study consists of a Main Report, five appendices, and 3 Annexes).

   Appendices I & II, Introduction, Study Area Today and Study Area Tomorrow–(to 2020), Corps of Engineers, North Atlantic Division, August 1971. Presents feasibility study on wastewater management in the Merrimack River Basin in the States of Massachusetts and N.H. Indicates the feasibility, including estimated costs, and the effects on the environment, of proposed wastewater pollution abatement methods and alternatives for the Basin.

   Appendix III, Development of Alternatives (Plan Formulation), Corps of Engineers, North Atlantic Division, August, 1971. Both conventional and physical-chemical wastewater treatment processes as well as land renovation techniques were investigated.

Existing projects utilizing these treatment processes and the quality of the reclaimed water and its uses are presented. The report sets out eight alternative solutions for dealing with water quality management.

Appendices IV & V, Assessment and Evaluation of Selected Alternatives, Corps of Engineers, North Atlantic Division, August, 1971. The various alternatives set forth in Appendix III are assessed in terms of ecologic, hygienic, aesthetic, social opportunity and economic criteria, as they relate to the characteristics of the Merrimack River Basin. Appendix V evaluates the effects and consequences of the impacts identified in Appendix IV.

Annex A, Consultant's Land and Water Disposal Assessments, Corps of Engineers, North Atlantic Division, August, 1971. A list of land and water disposal data prepared by private consultants for use in the Merrimack wastewater study.

Annex B, Consultant's Impact Assessment, Corps of Engineers, North Atlantic Division, August 1971. A list of impact assessment data prepared by private consultants for use in the Merrimack study.

Annex C, Consultant's Industrial Wastewater Profiles, Corps of Engineers, North Atlantic Division, August, 1971. A list of industrial wastewater data prepared by private consultants for use in the Merrimack Study.

2. *Open Planning/The Merrimack,* The New England Natural Resources Center, September, 1971. Presents a strategy for public involvement within the Merrimack River Basin.
3. *Aerial Remote Sensing Reconnaissance and Analysis of the Merrimack River* Basin, Coastal Research Corporation, March, 1972. Documents point source discharges into the Merrimack River and its major tributaries using remote sensing technology.
4. *Toxic Residual Elements and Compounds of the Merrimack River Watershed (Massachusetts Portion),* Lycott Environmental Research Company, October, 1973. Estimates quantities and types of residual compounds, i.e., pesticides, discharged into the waters of the Merrimack River Basin.
5. *Plan of Study, The Merrimack: Design for a Clean River,* North Atlantic Division, Corps of Engineers, NEWS Study, February, 1973.
6. *Merrimack Wastewater Management, Key to a Clean River,* Corps of Engineers, New England Division, November 1974. A joint survey study with the Commonwealth of Massachusetts and the U.S. Environmental Protection Agency addressing methods of improving wastewater management in the Merrimack River Basin in Massachusetts as well as the metropolitan area of Eastern Massachusetts. Consists of a Summary Report and the following 7 Appendices in 16 volumes.

Appendix 1—Background Information

Appendix 1-A, Geologic-Hydraulic Investigations, Anderson and Nichols, Inc., and Goldberg-Zoino, Inc., November, 1974. Presents surficial and bedrock geology as well as ground water hydrology data for the Eastern Massachusetts Area.

Appendix I-B, Industrial Listings, Anderson and Nichols, and Co., Inc. November, 1974. Lists various industries within study area and their estimated pollution contribution.

Appendix I-C, List of Study Criteria and Instruction, Corps of Engineers, New England Division, November, 1974. Lists various Federal and state criteria and instructions under which the study was accomplished.

Appendix II, Plan Formulation, Corps of Engineers, New England Division, November, 1974. Shows processes of determining various technical alternatives and recommended plan.

Appendix III, Volumes 1 & 11, Design and Costs, Anderson and Nichols, & Co., Inc., November, 1974. Present engineering information designs and costs of each wastewater management alternative.

Appendix IV Impact Analysis and Evaluation, Corps of Engineers, New England Division, November, 1974. Summarizes various impacts contained in Volumes IV A, B, C, and D.

Appendix IV-A, Socio-Economic Impacts, ABT, Associates Inc., November, 1974. Describes the sociological and economic impacts of the wastewater management alternatives.

Appendix IV-B, Volumes I & II, Biological Impacts, Normandeau Associates, Inc., November, 1974. Presents terrestrial and aquatic biological data and information for the Merrimack Basin. Describes biological impacts associated with each wastewater management alternative.

Appendix IV-C, Aesthetic Impacts, Anderson and Nichols, and Co., Inc., November, 1974. Delineates the visual and cultural impacts of each wastewater alternative.

Appendix IV-D, Hygienic — Public Health, Corps of Engineers, New England Division, November, 1974. Presents water quality data and findings of magnitude of pollution from non-point sources. Discusses existing sanitary waste practices within the Basin and suggests needed changes.

Appendix V, Institutional Arrangements, ABT, Associates, Inc. November, 1974. Describes existing authorities and management structures applicable to the study area and suggests modifications and changes that may be necessary to comply with the goals and requirements of PL 92-500. (Also Draft copy)

Appendix VI, Public Involvement Program, Corps of Engineers, New England Division, November, 1974. Lists public participation program for carrying out the study.

Appendix VII, Comments, Corps of Engineers, New England Division, November, 1974. Lists Federal, state and local comments on the Merrimack River Report.

7. *Wastewater Management — Merrimack River Basin — Boston Metropolitan Area,* Corps of Engineers, New England Division, December, 1975. Summarizes the wastewater management studies accomplished by the Corps of Engineers in the Merrimack River Basin and the Boston Metropolitan area in response to Congressional Resolutions.

V SOUTH CENTRAL PENNSYLVANIA STUDIES

1. *Preliminary Report: South Central Pennsylvania, Baltimore and Mason-Dixon Areas,* Corps of Engineers, North Atlantic Division, Baltimore District, February, 1970. An investigation of the urgent need areas of South Central Pennsylvania (York-Harrisburg-Lancaster) and Baltimore, and a preliminary analysis of the Mason-Dixon proposal.

2. *Identification and Assessment of Social and Economic Impacts, Codorus Creek Wastewater Management Study,* ABT Associates, Inc., November, 1971.

3 *The Codorus Creek Wastewater Management Study,* Corps of Engineers, North Atlantic Division, Baltimore District, April, 1973. A study of the alternatives which were developed to solve the water quality and related problems of the Codorus Creek Basin. The Report includes: (1) *Analysis of Conclusions: Summary of Findings and Recommendations,* April 1973, (2) *Summary Report and Conclusions,* August 1972, (3) Appendix A, Technical Studies, Vols. I - IV, August 1972, (4) Appendix B - Impact Studies, August 1972, (5) Appendix C, Analysis of Institutional Arrangements, August, 1973, and (6) Supplement to Appendix C - Implementing a Land-Based System — An Analysis of Approaches, August 1973.

4. *South Central Pennsylvania Metropolitan Area, Water Supply Development Alternatives,* Volume 1, Main Report. Corps of Engineers, North Atlantic Divsion, March 1975. This report is an investigation of the water supply situation in the Urban Metropolitan Areas of Harrisburg, Lebanon, York and Lancaster contained within the study area. Determinations were made of the magnitude and time of expected deficits in the UMA's and 13 alternative programs were investigated to determine engineering and cost solutions.

5. *South Central Pennsylvania Metropolitan Area, Water Supply Development Alternatives,* Volume 2, Appendices, Corps of Engineers, North Atlantic Division, March 1975.

Appendix 1, Technical Report For Water Supply Development Alternatives, Anderson-Nichols, Presents detailed data and methods used in the investigation, including population, supply, demand, deficits, engineering methodolgy and design criteria, cost methodology, construction phasing and design capacities and cost summaries.

Appendix 2A — Preliminary Assessment of Environmental, Social and Economic Impacts — Water Supply Development for the South Central Pennsylvania Area, Roy F. Weston, Inc., September, 1974. This study is preliminary assessment of environmental, social and economic impacts of the thirteen water supply alternatives for the study area. Analyses were conducted to determine beneficial or adverse effects from the point of view of these three disciplines, using categorical indicators and ranking systems.

Appendix 2B—Hydrologic Impact Studies of Alternatives to Meet Water Needs in South Central Pennsylvania, Resource Analysis, Inc., September, 1974. This report investigated the hydrologic effects of alternative water supply development in the area. The impact on streamflow from ground and surface water withdrawals by the different alternatives were investigated through the use of a simulation model. Results include the distribution of out flows from the system and on tributaries for each alternative. Studies were also made to determine the surface water response to ground water withdrawals.

Appendix 2C — Preliminary Study of Legal, Institutional and Cost Sharing Arrangements for Water Supply in South Central Pennsylvania, Booz, Allen and Hamilton, September, 1974. This study provides a preliminary analysis of possible legal, institutional and cost sharing arrangments necessary to implement alternative water supply programs in the area. It assesses these arrangements for selected engineering alternatives and applies two institutional options to a regional program. The report also presents implementation plans for the new institutional arrangements required by the regional program.